Research Bulletin 699 March, 1951

Soybean Oil Meal for Pigs

OHIO AGRICULTURAL EXPERIMENT STATION
WOOSTER, OHIO

CONTENTS

SOYBEAN OIL MEAL FOR PIGS

W. L. ROBISON

Experiments with soybean oil meal as a protein concentrate for growing and fattening pigs have been carried on by the author since 1916. It was not until about this time that soybean oil meal became available commercially in sufficient quantities to indicate a possibility of it becoming a feed of considerable economic importance.

Soybeans also were studied (18) as a high-protein feed for pigs. If they had proved satisfactory hogs could have been produced successfully on feeds grown on the farm and without the necessity of purchasing any feed for them other than a relatively small quantity of minerals.

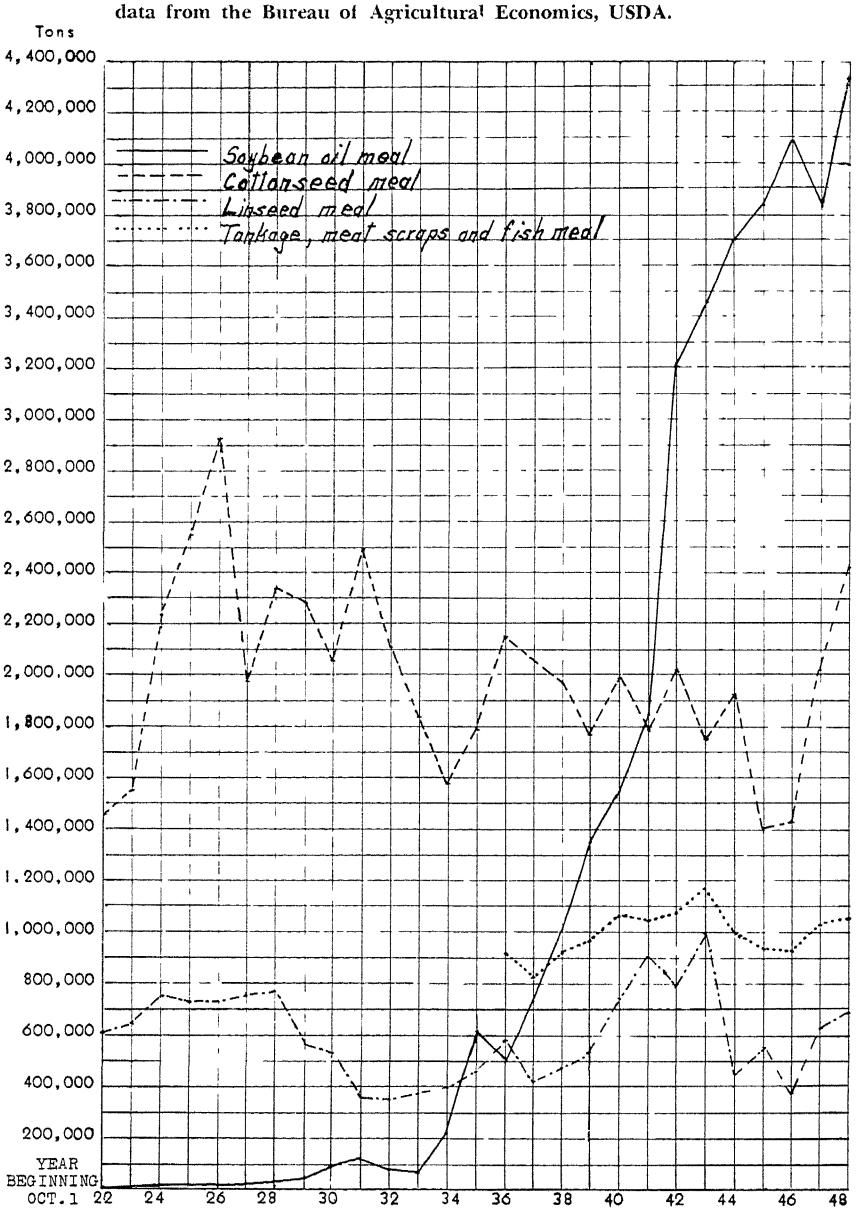
Soybeans were introduced into the United States as early as 1804. As long as they were used primarily for forage, only limited acreages were produced. They have only recently become a crop of major importance or of great economic value. The finding of ways of utilizing the beans, or rather the product derived from them, as a satisfactory and effective protein concentrate for livestock was largely responsible for the tremendous increase in the production of soybeans that took place in the two decades from 1929 to 1948.

Like the grains, soybeans are low in minerals. Adding minerals to the ration was beneficial both for pigs in dry lot and for pigs on pasture. High quality alfalfa or other leguminous hay may be thought of as something of a substitute for pasture. Regardless of the protein concentrate used, from 4 to 5 percent of such hay was beneficial for growing and fattening pigs that were not on pasture.

With minerals included in the ration when the pigs were on pasture, or minerals and alfalfa when they were not, soybeans were still an unsatisfactory protein concentrate, especially for young pigs. Soybeans were not as poor for well-grown shotes as they were for young pigs, nor for pigs on pasture as they were for those in dry lot.

From the standpoint of production, cooking soybeans changed them into an excellent protein supplement to corn and minerals for pigs on pasture, or to corn, minerals, and ground alfalfa for pigs in dry lot. From the standpoint of the resulting product, however, neither raw nor cooked soybeans are suitable for pigs intended for slaughter. Because of the oil they contain, if soybeans are fed with corn and make up much over 5 percent of the ration there is danger of them producing soft pork. Since a large share of the oil is removed in the manufacturing process, soybean oil meal is free from this objection.

Figure 1.—Annual production of linseed, cottonseed, and soybean oil meal and of tankage, meat scraps and fish scraps or meal in the United States. Based on data from the Bureau of Agricultural Economics, USDA.



Soybean oil meal is of further interest to swine men because it is now produced in greater abundance than is any other protein concentrate and, as a consequence, is commonly one of the more economical sources of protein. Figure 1 illustrates graphically the approximate annual production of soybean oil meal in the United States since 1922. For comparison, the approximate amounts of (1) cottonseed meal, (2) of linseed meal, and (3) of tankage, meat scraps, and fish meal combined produced annually are also shown.

A large production of soybeans has the advantage to swine producers of increasing the tonnage of protein concentrates available but the disadvantage of increasing the output of oil or a competitive product. Oil mills prefer high-oil varieties of soybeans, whereas low-oil varieties would be advantageous to swine producers. Markley (12) gives the maximum, average, and minimum fat content of soybeans as 24.2, 18.0, and 13.5 percent, respectively. Assuming a crush of 171,727,333 bushels of soybeans a year, which was the three-year average from 1946-1948, a loss of 3.3 percent in weight in milling, and a meal averaging 3.5 percent in fat, soybeans containing 18 percent of fat would produce 1,497,124,231 pounds of oil, whereas beans containing 24.2, and 13.5 percent of oil would produce 640,149,670 pounds more and 464,624,760 pounds less oil per year, respectively. Based on a populations of 151 million, this would be 4.24 pounds more and 3.08 pounds less per capita, respectively. A considerable portion of the soybean oil produced is used in vegetable shortening, which competes directly with lard and depresses the price of hogs.

Experiments (1) in which soybean oil meal and soybeans were compared, (2) in which soybean oil meals made in different ways were compared, (3) in which various materials for and methods of improving a ration of yellow corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast for pigs in dry lot were tried, and (4) in which soybean oil meal and other protein concentrates were compared are herein reported.

The prices used in computing the relative cost of feed per 100 pounds of gain in the various experiments are given in Table 1.

SOYBEANS UNSATISFACTORY

Nine experiments in which soybean oil meal was compared with raw soybeans as a high-protein feed for pigs in dry lot are summarized in Part A of Table 2. Approximately 4 percent of ground alfalfa was included in the rations in two of the nine experiments. The pigs fed the soybean oil meal required 14.1 percent less feed per 100 pounds

Table 1.—Schedule of Prices Used

	Protein approximate percent	Price per pound
Shelled corn		2.25c
Whole oats		2.25c
Fish meal	60	5.20c
Dry rendered tankage or meat scraps	60	5.00c
Meat and bone scraps	50	4.25c
Soybeans		2.75c
Expeller soybean oil meal	41	3.25c
Hydraulic soybean oil meal	41	3.25c
Solvent extracted soybean oil meal	44	3.50c
Linseed meal	34	3.00c
Cottonseed meal	41	3.25c
Soybean oil		10.00c
Soybean flour		4.00c
Soybean grits		4.00c
Dried brewers' yeast		10.00c
Condensed fish solubles		5.00c
Dried distillers' grain solubles		4.25c
Ground alfalfa		2.00c
Legume silage		0.30c
Irradiated yeast		90.00c
Mineral mixture*		3.00c
Cobaltous chloride		178.00c
Grinding corn or soybeans		.15c
Grinding oats		.25c
APF concentrate No. 1		50.00c
APF concentrate No. 2		133.00c
APF concentrate No. 3		43.00c
Baker's yeast		3.0 c a cake
Pasture, daily per pig		2.0 c

*Except in the early experiments in which no ferrous sulfate was used and in which equal parts of salt, limestone, and special steamed bone meal were fed, the minerals consisted of salt, 19.2; pulverized limestone, 38.4; special steamed bone meal, 38.4; ferrous sulfate, 4.0. Iodized salt was used from 1947 on.

Table 2.—Comparisons of Soybeans and Soybean Oil Meal as Protein Concentrates for pigs.

Experiments conducted from 1916 to 1927	Part A In dry lot		Part B On pasture	
	1 Corn **Soybeans**	2 Corn **Soybean oil meal**	1 Corn **Soybeans**	2 Corn **Soybean oil meal**
	Minerals*	Minerals*	Minerals	Minerals
Number of comparisons	9	9	2	2
Pigs at start	57	57	15	15
Initial weight per pig, lb.	53.1	52.9	53.9	54.0
Pigs at close	53	52	13	15
Final weight per pig, lb.	181.2	196.9	201.3	204.7
Average daily gain, lb.	.76	.99	1.33	1.54
Days to gain 160 pounds	210	163	121	105
Daily feed per pig, lb.:				
Corn	3.10	3.56	4.37	4.99
Soybeans	.53		.56	
Soybean oil meal		.47		.41
Ground alfalfa	.02	.03		
Minerals	.09	.10	.05	.06
Total	3.74	4.16	4.98	5.46
Feed, per 100 lb. gain, lb.:				
Corn	406.43	360.82	328.57	324.67
Soybeans	69.69		41.79	
Soybean oil meal		47.92		26.43
Ground alfalfa	3.24	2.94		
Minerals	11.17	9.60	4.00	3.72
Total	**490.53**	**421.28**	**374.36**	**354.82**
Cost of feed per 100 lb. gain	$12.18	$10.56	$ 8.98	$ 8.76
Cost of feed and pasture per 100 lb. gain**			$10.49	$10.06

* Ground alfalfa included in the rations in two of the nine experiments.

** Includes cost of pasture at 2.0c per pig per day.

Total pig days Lots 1 and 2 Part A, Lots 1 and 2 Part B, 8890, 7870, 1522, and 1470, respectively. Total gain Lots 1 and 2 Part A, Lot 1 and 2 Part B, 6775.167, 7765.5, 2023.0, and 2260.5 lbs., respectively.

gain and were ready for market 47 days earlier, on the average, than were those fed soybeans.

Two pasture experiments in which soybean oil meal and raw soybeans were compared are summarized in Part B of Table 2. The soybeans were less palatable and less nutritious than the soybean oil meal.

The pigs having the soybean oil meal ate 9.6 percent more feed daily per head, gained 15.8 percent more rapidly, were ready for market 16 days earlier and required 5.2 percent less feed per 100 pounds of gain than those having the soybeans.

A dry lot experiment and a pasture experiment in which soybean oil meal and cooked soybeans were compared as supplements to corn and minerals are reported in Parts A and B of Table 3.

Table 3.—Comparisons of Cooked Soybeans and Soybean Oil Meal as Protein Concentrates for Pigs.

	Part A In dry lot		Part B On pasture	
Experiments started: Dry lot, December 20, 1922 Pasture, July 6, 1923	1 Corn **Cooked soybeans**	2 Corn **Soybean Oil meal**	1 Corn **Cooked soybeans**	2 Corn **Soybean oil meal**
	Minerals	Minerals	Minerals	Minerals
Pigs at start	7	7	10	10
Initial weight per pig, lb.	49.0	47.2	47.1	47.1
Pigs at close	7	7	10	10
Final weight per pig, lb.	203.7	204.4	205.5	206.0
Average daily gain, lb.	**1.16**	**1.02**	**1.51**	**1.51**
Days to gain 160 pounds	138	157	106	106
Daily feed per pig, lb.:				
Corn	3.34	3.49	4.71	4.94
Cooked soybeans	.69		.52	
Soybean oil meal		.44		.40
Minerals	.11	.12	.08	.08
Total	4.14	4.05	5.32	5.42
Feed per 100 lb. gain, lb.:				
Corn	287.25	341.76	312.60	326.75
Cooked soybeans	59.73		34.77	
Soybean oil meal		42.98		26.34
Minerals	9.18	11.90	5.30	5.29
Total	**356.16**	**396.64**	**352.67**	**358.38**
Feed per 100 lb. gain with fat × 2.25*	382.65	415.77	374.99	375.68
Cost of feed per 100 lb. gain	$ 9.26	$ 9.96	$ 8.67	$ 8.86
Cost of feed and pasture per 100 lb. gain			$10.00**	$10.18**

* Assuming the corn, cooked soybeans, and soybean oil meal contained 3.8, 17.2, and 5.4 percent of fat, respectively.

** Includes cost of pasture at 2.0c per pig per day.
Total pig days, Lots 1 and 2 Part A, Lots 1 and 2 Part B, 931, 1078, 1050, and 1050, respectively.

Total gain, Lots 1 and 2 Part A, Lots 1 and 2 Part B, 1083.0, 1100.5, 1583.5, and 1589 pounds, respectively.

In the dry lot experiment the pigs fed soybean oil meal gained more slowly, were ready for market 19 days later, and required 11.4 percent more feed per 100 pounds of gain than those fed cooked soybeans. By multiplying the estimated fat in each ration by 2.25 it is possible to closely equalize the energy values of the two rations. On an equivalent energy basis, the pigs fed soybean oil meal required 8.7 percent more feed per unit of gain than those fed cooked soybeans.

The two groups on pasture showed practically no difference in either the rate of growth or the feed required per unit of gain on an equivalent energy basis.

In the Ohio experiments the soybeans were boiled. Vestal (25) found that roasted soybeans also were superior to raw soybeans for pigs.

Although soybean oil meal was not superior to cooked soybeans as a supplement to corn for pigs, so far as production was concerned, it has the advantage of being free from the danger of producing soft pork.

METHODS OF MANUFACTURING SOYBEAN OIL MEAL

Early experiments showed wide variations in the value of soybean oil meals when they were used as the only protein concentrate in rations for pigs. Some soybean oil meals gave good results. Others gave as poor results as raw soybeans.

Three methods are used in removing oil from soybeans. These are the hydraulic, which is a batch method; the expeller or continuous screw-type press method; and the solvent extraction process, which is a chemical method. Savings of a third or more in the operating costs of the solvent extraction method were effected by replacing the older batch systems with continuous systems of extraction. These were first developed in Germany. A history of the early development of continuous systems of extracting oil from soybeans with a solvent has been given by Schmidt (22). Goss (6) has given detailed descriptions of the three methods of manufacturing soybean oil meal.

A number of factors, including the moisture present and the percentage of oil removed from the beans, influence the protein content of soybean oil meals. Usually mechanically pressed soybean oil meals are sold to contain 41 percent of protein. Improved techniques and equipment have enabled the removal of a larger percentage of the oil from soybeans so that some companies are now (1950) marketing screw pressed meals containing more than 41 percent protein. Solvent extracted soybean oil meals are lower in oil and, as a consequence, are higher in the other constituents that were present in the beans. Usually they are sold to contain 44 percent or more protein.

The larger share of the soybean oil meal manufactured in this country has been made with expeller or continuous screw-type presses. Since it removes more of the oil and oil brings a higher price per pound than the meal, the percentage of soybean oil meal produced annually that is made by the solvent extraction method is increasing. The trend was retarded somewhat by World War II but since then has been proceeding at an accelerating rate.

From 1936 to 1938, inclusive, 13.6, 70.7, and 15.7 percent of the soybean oil meal manufactured in the United States was produced by the hydraulic, the continuous screw-type press, and the solvent extraction method, respectively. From 1946 to 1948, inclusive, 7.5, 57.8, and 34.7 percent of the soybeans used for the production of meal were processed by the hydraulic, the continuous screw-type press, and the solvent extraction method, respectively.

NORMAL AND HIGHER TEMPERATURE HYDRAULIC MEALS

Four trials in which standard hydrualic or old process soybean oil meals were compared with good quality expeller soybean oil meal are summarized in Part A of Table 4. Ground alfalfa was included in the rations only in the latest one of the four tests. The pigs fed the hydraulic meals ate 9 percent less feed daily a head, gained 81.6 percent as rapidly and required 10.9 percent more feed per unit of gain than those fed expeller soybean oil meals.

At the time the hydraulic soybean oil meals used in the experiments reported in Part A of Table 4 were made, the beans were customarily cooked at a temperature of 105 degrees C. or 221 degrees Fahrenheit for 1.5 hours. It was found that if corrugated press boards were used a higher temperature could be employed without danger of burning the expensive camels' hair mats in which the cooked beans were placed for pressing. Part B of Table 4 gives the results of a test in which a hydraulic soybean oil meal made from beans that were cooked at a temperature of approximately 120° C. or 248 degrees F. for 1.5 hours was fed. The higher temperature hydraulic soybean oil meal and the expeller soybean oil meal with which it was compared were supplied through the courtesy of Archer-Daniels-Midland Company. The pigs fed the higher temperature hydraulic soybean oil meal ate 3.4 percent more feed daily a head, gained 8.9 percent more rapidly, were ready for market 10 days earlier and required 4.8 percent less feed per unit of gain than those fed a good quality expeller soybean oil meal.

In tests by Hayward et al. (8) with pigs averaging 88 pounds at the start, those fed a 121°C. hydraulic meal gained 9.6 percent more rapidly

Table 4.—Comparisons of Hydraulic and Expeller Soybean Oil Meals as Protein Concentrates for Pigs.

	Part A Hydraulic soybean oil meal; former normal temperature. Cooking temperature, 105°C. for 1.5 hours		Part B Hydraulic soybean oil meal; higher temperature. Cooking temperature, 120°C. for 1.5 hours	
Years experiments were conducted: Part A, 1923-1926 Part B, 1936	1 Corn **Hydraulic soybean oil meal** Minerals*	2 Corn **Expeller soybean oil meal** Minerals*	1 Corn **Higher temperature hydraulic soybean oil meal** Ground alfalfa Minerals	2 Corn **Expeller soybean oil meal** Ground alfalfa Minerals
Number of comparisons	4	4	1	1
Pigs at start	25	25	15	15
Initial weight per pig, lb.	49.1	49.2	42.1	42.5
Pigs at close	22	22	15	14
Final weight per pig, lb.	185.0	199.9	210.5	206.3
Average daily gain, lb.	**0.80**	**0.98**	**1.34**	**1.23**
Days to gain 160 pounds	200	164	120	130
Daily feed per pig, lb.:				
Corn	3.14	3.43	3.75	3.63
Soybean oil meal	.41	.46	.83	.80
Ground alfalfa	.02	.02	.19	.19
Minerals	.07	.09	.11	.10
Total	3.64	4.00	4.88	4.72
Feed per 100 lb. gain, lb.:				
Corn	391.08	350.82	280.70	294.84
Soybean oil meal	50.88	46.75	61.93	65.16
Ground alfalfa	2.19	2.38	14.61	15.35
Minerals	9.29	8.96	8.01	8.42
Total	**453.44**	**408.91**	**365.25**	**383.77**
Cost of feed per 100 lb. gain	$11.36	$10.26	$ 9.28	$ 9.75

* Ground alfalfa included in the rations in one of the four comparisons.

Total pig days, Lots 1 and 2 Part A, Lots 1 and 2 Part B, 3878, 3598, 1890, and 1939, respectively. Total gain Lots 1 and 2 Part A, Lots 1 and 2 Part B, 3114.5, 3515.5, 2526.5, and 2386.333 lb., respectively.

and required 3.4 percent less feed per unit of gain than those fed a 105°C. hydraulic meal.

LOW AND HIGHER TEMPERATURE EXPELLER MEALS

Four trials in which disagreeable raw bean-like tasting expeller soybean oil meals, or meals made at relatively low temperatures, were compared with expeller soybean oil meals having a pleasing roasted nut-like taste and aroma, or meals made at higher temperatures are

summarized in Table 5. Three of the experiments were early ones in which no ground alfalfa was included in the rations. In one of the comparisons the pigs were fed twice daily. In the others they were self fed.

Table 5.—Raw Tasting and Roasted, Nut-like Expeller Soybean Oil Meals as Protein Concentrates for Pigs.

Years experiments were conducted: 1923, 1924, and 1942	1 Corn **Raw tasting expeller soybean, oil meal** Minerals*	2 Corn **Roasted nut-like expeller soybean oil meal** Minerals*
Number of comparisons	4	4
Pigs at start	33	33
Initial weight per pig, lb.	45.0	45.1
Pigs at close	22	28
Final weight per pig, lb.	168.5	196.4
Average daily gain, lb.	**0.64**	**0.95**
Days to gain 160 pounds	251	169
Daily feed per pig, lb.:		
Corn	2.51	3.07
Soybean oil meal	.46	.53
Ground alfalfa	.05	.07
Minerals	.07	.08
Total	3.09	3.75
Feed per 100 lb. gain, lb.:		
Corn	392.87	324.08
Soybean oil meal	71.89	56.02
Ground alfalfa	7.97	6.77
Minerals	9.93	8.19
Total	**482.66**	**395.06**
Cost of feed per 100 lb. gain	$12.22	$ 9.98

* Ground alfalfa was included in the ration in one experiment.
Total pig days, Lot 1, 4585; Lot 2, 4718; total gain, Lot 1, 2931.0; Lot 2, 4472.667 lb., respectively.

In each of the four trials the raw bean-like tasting meals gave unsatisfactory results. The pigs receiving them ate 17.6 percent less feed daily a head, required 22.2 percent more feed per unit of gain produced, gained only 67.4 percent as rapidly and were not ready for market until 82 days later, on the average, than those receiving the roasted, nut-like expeller meals. The raw tasting expeller meals gave relatively as poor results as raw soybeans. As shown in Table 2, pigs

fed raw soybeans required 16.4 percent more feed per unit of gain and gained 76.8 percent as rapidly as pigs fed roasted, nut-like expeller soybean oil meals.

Unless otherwise noted, the expeller soybean oil meals used in the experiments reported in the other tables were relatively high temperature or good quality meals.

NON-TOASTED AND TOASTED SOLVENT EXTRACTED MEALS

Only nominal temperatures are required in the various steps of removing oil from soybeans by the solvent extraction method. Originally the extracted flakes were freed from solvent, ground and sold without further processing. The resulting meal was light in color and had no pronounced aroma.

The results of seven experiments in which non-toasted, solvent extracted soybean oil meal was tried for pigs are given in Part A of Table 6. In the three earliest of the seven tests no ground alfalfa was included in the rations. In one of the three the feeds were given twice daily. In another the ground corn, protein concentrate, and minerals were self-fed separately. In the other five of the seven trials the corn was ground, the various ingredients in the rations were mixed and the mixtures were self fed.

The pigs having non-toasted solvent extracted soybean oil meal ate 15.5 percent less feed daily a head, required 21.8 percent more feed per unit of gain produced, and were not ready for market until 62 days later, on the average, than those having good quality expeller soybean oil meal. Like raw-tasting expeller soybean oil meals, non-toasted solvent extracted soybean oil meals resulted in little or no better relative performance than raw soybeans.

The solvent employed when the meals for the first three of the seven tests were made was benzol. That employed when the meals for the last four tests were made was hexane. In the first three trials the pigs fed the non-toasted solvent extracted soybean oil meals gained 33.8 percent less rapidly and required 27.0 percent more feed per unit of gain than those fed expeller soybean oil meals. In the last four trials the pigs fed the non-toasted extracted soybean oil meals gained 30.4 percent less rapidly and required 20.5 percent more feed per unit of gain than those fed expeller soybean oil meals.

After experiments showed that poor results were obtained from non-toasted solvent extracted soybean oil meals, some manufacturers began putting the flakes through an additional process of cooking or

Table 6.—Non-toasted, Moderately Toasted, and Thoroughly Toasted Solvent Extracted Soybean Oil Meals for Pigs.

Experiments conducted: Part A, 1923, 1924, 1934, 1935, 1936 Part B, 1935 and 1936 Part C, 1939, 1942, 1946	Part A Non-toasted solvent extracted soybean oil meal		Part B Moderately toasted solvent extracted soybean oil meal		Part C Thoroughly toasted solvent extracted soybean oil meal	
	1 Extracted soybean oil meal Ground alfalfa Minerals	2 Expeller soybean oil meal Ground alfalfa Minerals	1 Extracted soybean oil meal Ground alfalfa Minerals	2 Expeller soybean oil meal Ground alfalfa Minerals	1 Extracted soybean oil meal Ground alfalfa Minerals*	2 Expeller soybean oil meal Ground alfalfa Minerals*
Number of comparisons	7	7	3	3	4	4
Pigs at start	63	65	36	36	51	51
Initial weight per pig, lb.	52.9	52.8	56.0	56.1	49.9	49.9
Pigs at close	57	55	29	30	44	45
Final weight per pig, lb.	188.8	208.0	212.0	211.0	209.9	207.9
Average daily gain, lb.	**.80**	**1.15**	**1.09**	**1.20**	**1.14**	**1.05**
Days to gain 160 pounds	202	140	147	133	141	153
Daily feed per pig, lb.:						
Corn	3.07	3.64	3.66	3.67	3.41	3.14
Soybean oil meal	.59	.70	.74	.81	.76	.77
Ground alfalfa	.11	.12	.19	.19	.19	.17
Minerals	.08	.10	.10	.11	.10	.09
Total	3.85	4.56	4.69	4.78	4.46	4.17
Feed per 100 lb. gain, lb.:						
Corn	385.51	317.47	335.75	304.67	299.72	299.91
Soybean oil meal	74.30	60.85	67.65	67.31	67.22	73.53
Ground alfalfa	14.20	10.76	17.21	15.84	16.44	16.78
Minerals	10 69	8.74	9.64	8.75	8.37	8.26
Total	**484.70**	**397.82**	**430.25**	**396.57**	**391.75**	**398.48**
Cost of feed per 100 lb. gain	$12.46	$10.07	$11.14	$10.08	$10.13	$10.18

* Irradiated yeast as a source of vitamin D was fed in the latest of the four experiments. It was fed at the rate of 0.01 per cent of the ration.

Total pig days, Lots 1 and 2 Part A, 1 and 2 Part B, and Lots 1 and 2 Part C, 9704, 7903, 4326, 4095, 6412, and 6860, respectively. Total gain Lots 1 and 2 Part A, Lots 1 and 2 Part B, and Lots 1 and 2 Part C, 7715.5, 9060.0, 4714, 4933.333, 7297.167, and 7178.667 pounds, respectively.

toasting following the removal of the oil. Part B of Table 6 shows the effect on the performance of pigs of moderately cooking and Part C of thoroughly cooking the solvent extracted flakes previous to grinding them into meal.

The pigs fed the non-toasted, moderately toasted, and thoroughly toasted solvent extracted soybean oil meals in the experiments reported in Parts A, B, and C of Table 6 gained 0.8, 1.09, and 1.14 pounds daily a head and required 485, 430, and 392 pounds of feed per 100 pounds of gain produced, respectively. The pigs with which they were compared and that were fed good quality expeller soybean oil meal gained 1.15, 1.20, and 1.05 pounds daily a head and required averages of 398, 397, and 398 pounds of feed per 100 pounds of gain produced, respectively.

Moderately cooked solvent extracted soybean oil meal produced gains 9.2 percent less rapidly and on 8.5 percent more feed per unit of gain than good quality expeller soybean oil meal. Thoroughly cooked solvent extracted soybean oil meal produced gains 8.6 percent more rapidly and on 1.7 percent less feed per unit of gain than good quality expeller soybean oil meal.

The average daily gain of 1.05 pounds was lower than was typical from good quality expeller soybean oil meal. Nevertheless, thorough cooking or toasting, as against non-toasting, changed solvent extracted soybean oil meal from a feed which gave much poorer results to one which gave fully as good results as good quality expeller soybean oil meal

EFFECT OF MANUFACTURING PROCEDURES ON WORTH OF EXPELLER MEALS

Efforts to improve the equipment and the procedures for removing oil from soybeans and other oil-bearing materials are constantly going on. Since they were first developed, various improvements in the construction and use of expellers or continuous screw-type presses have been made. The effects of the procedures of pre-heating the beans, of lowering their moisture content before allowing them to enter the expeller barrel and of adjusting the opening through which the pressed cake is discharged from the expeller on the friction and temperature developed and on the quality of the meal produced were shown in the preceding data. A further development in the equipment was oil cooling. Oil cooling is accomplished by pumping soybean oil from the collection trough beneath the main barrel of the expeller, lowering its temperature to a point not exceeding 200°F., and using it to flush both the vertical and horizontal barrels of the expeller.

In this way the temperature within the barrels or pressing chambers is lowered as much as 80°F. or more.

A considerably higher price for oil than for meal is a strong incentive for the manufacturer to attempt to secure a maximum yield of oil. With the procedures which were commonly followed, when as much oil as practicable was removed with Super Duo Oil Cooled Expellers, the inner portion of the cake was scorched, caramelized or darkened to some depth. By subjecting the beans to a lower temperature in the drier and flaking or rolling them to a thickness of 1/16 to 1/32 of an inch instead of cracking or coarsely grinding them, as high a yield of oil can be obtained and the double layer effect or darkening of the inner portion of the cake to so great a depth can be avoided.

An experiment was conducted to secure data on the feeding values for pigs of toasted solvent extracted soybean oil meal and of expeller soybean oil meals made by various procedures. The V. D. Anderson Company provided financial support for the experiment and also manufactured the expeller meals. The Central Soya Company assisted with the experiment by manufacturing and furnishing the toasted solvent extracted soybean oil meal and by selling the soybeans from which the expeller soybean oil meals were made. A flow of beans was split so that the solvent extracted and the expeller meals would be made from the same supply of soybeans.

Mr. F. W. Weigel of the V. D. Anderson Company and Mr. Norman H. Kruse of the Central Soya Company were in charge of the manufacture of the meals. Mr. Weigel and his assistants gave the manufacture of the different expeller meals close supervision and collected the moisture and temperature data on the beans and the meals.

Oil cooling was used in the manufacture of the Super Duo but not in the manufacture of the Duo expeller meals.

The soybeans for the manufacture of the meal fed Lot 4 in the experiment reported in Table 7 were rolled or flaked rather than cracked or coarsely ground, as they were for the manufacture of the other expeller meals used in the experiment and as was the common practice. Furthermore, the beans for the manufacture of the meal fed Lot 4 were not subjected to as high a temperature in the drier as were those for the manufacture of the other expeller meals.

Samples of the different soybean oil meals were taken at the Experiment Station for analyses by the Nutrition Division of the Department of Animal Science of the Station, the V. D. Anderson Company, and the Central Soya Company. The moisture, protein, and fat contents given in Table 7 are the averages of the three analyses.

To bring out more clearly, differences, if any, in the nutritive values of the meals, young pigs 7 to 10 weeks of age and averaging 38 pounds

in weight at the start of the test, rather than older pigs, were used. The pigs were confined indoors during the tests.

At the beginning it was intended to rely on the sun-cured alfalfa to supply an ample amount of vitamin D. However, since the pigs were indoors, it was decided later to avoid any possibility of a vitamin D deficiency by fortifying the rations with irradiated yeast. Accordingly, after the eighth week, irradiated yeast at the rate of 0.01 percent of the total feed was fed. A pound of the irradiated yeast was pre-mixed with 100 pounds of corn and a pound of this was substituted for a pound of the other corn in each 100 pounds of feed.

Before and after each group of pigs averaged 125 pounds in weight, whatever quantities of the soybean oil meals were required to provide rations containing 16.6 and 14.6 percent of protein, respectively, were used. The approximate mineral content, including that in the feeds and that added, ranged from 4.3 to 4.6 percent. Soybean oil was added to all of the rations except that for Lot 1, in whatever amounts were needed to equalize the fat contents so that each ration contained approximately 3.8 percent of fat. Ground alfalfa made up 5 and added minerals, 2 percent of the rations.

The temperatures and moisture contents of the beans and meals at various stages of manufacture, the moisture, protein, and fat contents of the manufactured meals and the results secured from them in the feeding experiment are shown in Table 7.

Apparently the rations were deficient in some respect. Instead of the rapidity of the gains continuing to increase until a weight of 200 pounds was reached, as is typical of normally developing pigs of similar type, that of all the groups slowed down before the experiment was concluded. The pigs showed a tendency to become excessively fat rather than to grow or develop normally. A number of them became wrinkly and rough in the skin. Several had a wheezy respiration. Some were removed from their respective lots because they had ceased to gain or were losing in weight. Two groups of pigs similarly fed except that their rations contained a combination of expeller soybean oil meal and 60 percent protein meat scraps gained rather slowly at first but more rapidly later and otherwise developed normally. In some, but not all, of the other dry lot experiments in which it was used pigs fed a ration of yellow corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast responded in a similar manner to those in this test.

As indicated by faster gains, greater gains per unit of feed, and fewer removals, duo expeller soybean oil meal made from beans that were heated to a high temperature in the drier and that were low in

Table 7.—Comparison of Soybean Oil Meals Made by Different Equipment and Procedures.

Experiment started June 10, 1942 Feeds mixed and self fed	1	2	3	4	5
	Ground yellow corn, ground alfalfa, and minerals*				
	Duo expeller soybean oil meal	**Duo expeller soybean oil meal higher temperature**	**Super duo oil cooled expeller soybean oil meal from coarsely ground beans**	**Super duo oil cooled expeller soybean oil meal from flaked beans**	**Toasted solvent extracted soybean oil meal**
Temperature of beans in drier, °F	260	273	270	236	. . .
Temperature, entering expeller, °F	270	280	280	260	"
Moisture, beans leaving drier, %	2.04	1.70	2.64	3.48	. " "
Moisture, beans entering expeller, %	1.40	1.02	1.76	2.68	.
Maximum temperature expeller barrel, °F	313	320	238	238	.
Moisture in meal, %	8.68	9.50	10.51	11.02	9.39
Protein in meal, %	45.30	45.30	45.40	45.20	46.70
Fat in meal, %	4.61	4.17	3.37	3.53	0.97
	Entire Time — June 10 to November 25, 1942				
Pigs at start	13	13	13	12	13
Initial weight per pig, lb.	38.5	38.8	38.6	37.8	38.4
Pigs at close	7	10	11	11	10
Final weight per pig, lb.	167.1	186.0	183.4	184.3	214.1
Average daily gain, lb.	**0.65**	**0.84**	**0.85**	**0.86**	**1.01**
Days to gain 160 pounds	247	190	189	187	159
Daily feed per pig, lb.:					
Corn	1.95	2.39	2.31	2.34	2.66
Soybean oil meal	.54	.64	.61	.61	.66
Soybean oil		.003	.01	.01	.03
Ground alfalfa	.13	.16	.16	.16	.18
Minerals	.05	.07	.06	.06	.07
Total	2.67	3.26	3.15	3.18	3.60
Feed per 100 lb. gain, lb.:					
Corn	300.27	283.09	273.11	272.71	264.66
Soybean oil meal	82.96	75.19	71.91	71.86	65.69
Soybean oil		.39	.97	.96	2.52
Ground alfalfa	20.61	19.29	18.60	18.58	17.89
Minerals	8.24	7.71	7.44	7.43	7.16
Total	**412.08**	**385.67**	**372.03**	**371.54**	**357.92**
Cost of feed per 100 lb. gain	$10.59	$ 9.92	$ 9.61	$ 9.59	$ 9.50

* Soybean oil was added to equalize the fat content of the rations. Irradiated yeast at the rate of 0.01 percent of the ration as a source of vitamin D was added after the first 8 weeks.

Total pig days, Lots, 1, 2, 3, 4, and 5, 1792, 2044, 2002, 1960, and 1974, respectively.

Total gain, Lots 1, 2, 3, 4, and 5, 1139.5, 1680.667, 1707.667, 1639.667, and 1934.333 pounds, respectively.

moisture when they entered the expeller was worth more than duo expeller meal made from beans that did not reach as high a temperature in the drier or that were not as low in moisture when they entered the expeller.

As judged by the greater gains per unit of feed consumed, the meal manufactured in a super duo oil cooled expeller was superior for pigs to that manufactured in a duo expeller that was not oil cooled. The maximum temperature in the barrel of the oil cooled expeller was 238° F. whereas that in the barrel of the expeller that was not oil cooled was 320° F.

The results from the meals made from flaked and from coarsely ground soybeans in a super duo oil cooled expeller were inconclusive. Possibly they were obscured by the deficiency in the rations or by conflicting influences. For the entire time there was practically no difference in the average daily gains or in the average amounts of feed required per unit of gain from the meals made by the two procedures.

Table 8 gives the results secured from the various rations during the growing period or fore part of the experiment and during the fattening period or latter part of the experiment. During the growing period the pigs fed the meal made from the flaked soybeans required 10.3 percent less, whereas during the fattening period they required 19.6 percent more feed per unit of gain than those fed the meal made from the coarsely ground soybeans. The data for the latter part of the experiment or for the entire time did not indicate a danger of excessive temperatures, so far as the worth of the meal for pigs was concerned, when the meal was made in a super duo oil cooled expeller under practical operating conditions. However, if the data for the early part of the experiment were typical, meal made from soybeans which were not heated to so high a temperature in the drier and which was flaked was superior to meal made from soybeans which had been heated to a high temperature in the drier and which were coarsely ground.

Like the results secured from the meals made from the coarsely ground and from the flaked soybeans in a super duo oil cooled expeller the results secured from the toasted solvent extracted soybean oil meal were not entirely consistent, or, when considered alone, too positive in character. During the fattening period, the pigs fed the toasted solvent extracted soybean oil meal made less gain per unit of feed than the pigs fed the meal made from the coarsely ground soybeans in the super duo oil cooled expeller or those fed the high temperature duo expeller meal. During the growing period, the pigs fed the toasted solvent extracted soybean oil meal made more rapid gains and greater gains

Table 8.—Comparison of Soybean Oil Meals Made by Different Equipment and Procedures.

	Ground yellow corn, ground alfalfa, and minerals*				
	1	2	3	4	5
	Duo expeller soybean oil meal	**Duo expeller soybean oil meal higher temperature**	**Super duo oil cooled expeller soybean oil meal from coarsely ground beans**	**Super duo oil cooled expeller soybean oil meal from flaked beans**	**Toasted solvent extracted soybean oil meal**
	Growing Period				
Initial weight per pig, lb.	38.5	38.8	38.6	37.8	37.3
Final weight per pig, lb.	135.1	124.7	123.5	134.2	138.4
Average daily gain, lb.	**0.63**	**0.76**	**0.75**	**0.84**	**0.96**
Daily feed per pig, lb.	2.41	2.94	2.75	2.77	2.96
Feed per 100 lb. gain, lb.	**385.51**	**384.53**	**368.32**	**330.50**	**307.46**
	Fattening Period				
Initial weight per pig, lb.	135.1	124.7	123.0	134.2	138.4
Final weight per pig, lb.	167.1	186.0	183.4	184.3	214.1
Average daily gain, lb.	**0.76**	**1.03**	**1.08**	**0.89**	**1.08**
Daily feed per pig, lb.	3.96	4.01	4.07	4.04	4.71
Feed per 100 lb. gain, lb.	**520.36**	**387.67**	**377.86**	**452.04**	**435.12**

* Soybean oil was added to equalize the fat content of the rations. Irradiated yeast at the rate of 0.01 percent of the ration as a source of vitamin D was added after the first 8 weeks.

per unit of feed consumed than those fed any of the other meals. After the 24 weeks on feed they averaged 30 pounds heavier than those in the next best lot. At the heavier final weight and with the expeller meal figured at 3.25 and the toasted solvent extracted meal at 3.5 cents a pound, their feed cost per 100 pounds of gain was 9 cents less than that of the next best lot. At approximately the same final weight it was 50 cents less. The data for the entire time agree with those reported in Part C of Table 6 in indicating that, on an equivalent protein basis, thoroughly toasted solvent extracted soybean oil meal was fully equal if not slightly superior to good quality expeller soybean oil meal.

SOYBEAN OIL MEAL RATION INADEQUATE IN DRY LOT FEEDING

For a number of years the trio mixture of tankage, linseed meal, and ground alfalfa was a standard with which other supplements were compared. Part A of Table 9 reports 10 experiments in which expeller soybean oil meal was tried as a complete substitute for a mixture of dry rendered tankage or 60 percent protein meat scraps and linseed meal as a protein concentrate for pigs in dry lot. Both groups were fed ground alfalfa and minerals. In five of the tests the meat scraps and linseed meal were fed in a 2:1 ratio and in the other five, they were fed in a 1:1 ratio.

In three of the same and in two other experiments, toasted solvent extracted soybean oil meal was likewise compared with a mixture of meat scraps and linseed meal for feeding with yellow corn, ground alfalfa, and minerals to pigs in dry lot. In two of these comparisons the meat scraps and linseed meal were fed in a 2:1 ratio. In three they were fed in a 1:1 ratio. Part B of Table 9 summarizes the five comparisons.

The pigs fed expeller soybean oil meal as a protein concentrate ate 15.2 percent less feed daily a head, gained 17.6 percent less rapidly, were ready for market 25 days later, on the average, and required 1.8 percent more feed per unit of gain than those fed a mixture of meat scraps and linseed meal.

The pigs fed the toasted solvent extracted soybean oil meal as a protein concentrate ate 16.1 percent less feed daily a head, gained 15.8 percent less rapidly, were ready for market 21 days later, on the average, and required 0.6 percent less feed per unit of gain than those fed a mixture of meat scraps and linseed meal.

Good quality soybean oil meal, whether it was made by the expeller or by the toasted solvent extraction process, resulted in economical

gains. There were serious objections to it, however, when it was used as the sole protein concentrate with corn, ground alfalfa, minerals, and irradiated yeast for pigs in dry lot.

The pigs in the experiments reported in Table 9 were carried from approximately 50 to 210 pounds in weight. They were on forage plots

Table 9.—Soybean Oil Meal and a Combination of Meat Scraps and Linseed Meal as Protein Concentrates for Pigs in Dry Lot.

Experiments conducted Part A, 1931 to 1946 Part B, 1939 to 1946	Part A **Expeller Soybean Oil Meal**		Part B **Toasted Solvent Extracted Soybean Oil Meal**	
	1 Corn **Meat scraps** **Linseed meal** Ground alfalfa Minerals	2 Corn **Expeller soybean oil meal** Ground alfalfa Minerals	1 Corn **Meat scraps** **Linseed meal** Ground alfalfa Minerals	2 Corn **Toasted solvent extracted soybean oil meal** Ground alfalfa Minerals
Number of comparisons	10	10	5	5
Pigs at start	125	125	66	66
Initial weight per pig, lb	53.8	53.7	52.7	53.3
Pigs at close	118	105	65	60
Final weight per pig, lb.	212.9	212.7	215.8	208.4
Average daily gain, lb.	**1.36**	**1.12**	**1.39**	**1.17**
Days to gain 160 pounds	118	143	116	137
Daily feed per pig, lb:				
Corn	4.34	3.44	4.45	3.57
Meat scraps	.44		.46	
Linseed meal	.32		.38	
Soybean oil meal		.81		.82
Ground alfalfa	.21	.17	.22	.19
Minerals	.07	.10	.07	.10
Total	5.38	4.52	5.58	4.68
Feed per 100 lb. gain, lb.:				
Corn	318.15	305.81	319.94	304.49
Meat scraps	32.53		33.09	
Linseed meal	23.48		27.31	
Soybean oil meal		71.77		69.78
Ground alfalfa	15.30	15.58	16.06	15.98
Minerals	5.33	8.79	5.26	9.13
Total	**394.79**	**401.95**	**401.66**	**399.38**
Cost of feed per 100 lb. gain	$10.43	$10.25	$10.63	$10.29

Total pig days, Lots 1 and 2 Part A, Lots 1 and 2 Part B, 13,979, 15,505, 7,637, and 8113, respectively.

Total gain Lots 1 and 2 Part A, Lots 1 and 2 Part B, 19,042.0, 17,436.833, 10,609.0, and 9,505.167 pounds, respectively.

until the start of the experiments. Since relatively large numbers were kept on rather limited areas, the pasture was sometimes exhausted before the pigs were removed from the plots for starting on the tests.

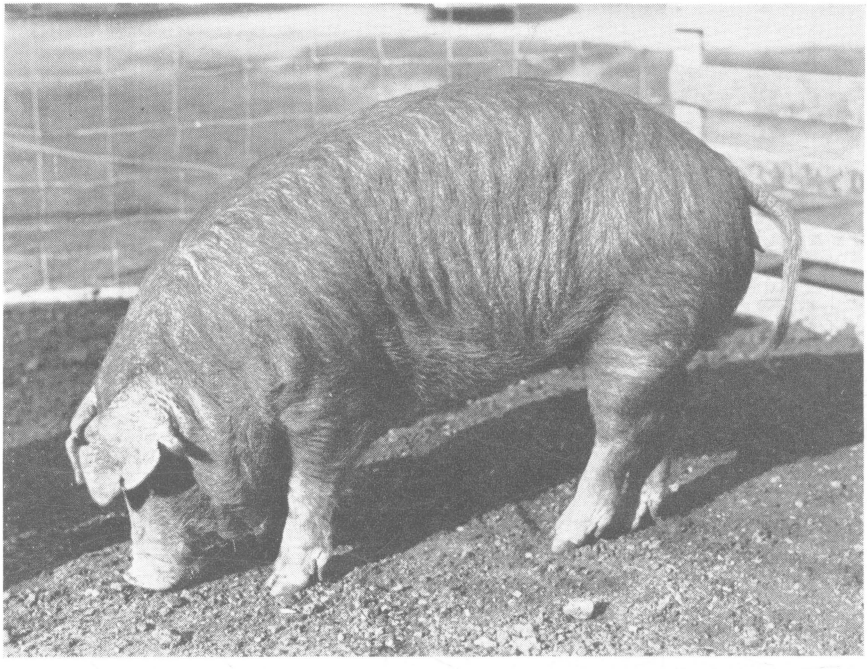


Figure 2.—A pig representative of those that ceased to gain normally, became wrinkly and rough in the skin and developed a wheezy respiration. Such pigs sometimes died after little exertion. Ration: corn, soybean oil meal, ground alfalfa—5 percent of ration, limestone, special steamed bone meal and ferrous sulfate. Av. daily gain, first 84 days, 0.78 lb.; next 42 days, 0.40 lb.

Instead of developing normally during the course of the experiments some of the pigs fed soybean oil meal became excessively fat. Some became wrinkly and rough in the skin. A number developed a wheezy respiration. They could stand little exertion. Some of them died when attempts were made to drive them a short distance, as for weighing. The wheezy condition was not encountered in all of the tests. Rather than continuing to gain at an increasingly rapid rate, as is typical of pigs that are thriving, a number of them reached a point at which they ceased to gain or began losing weight. Because of becoming unthrifty and ceasing to gain, a larger percentage of the pigs fed soybean oil meal than of those fed a mixture of tankage and linseed meal were removed from their respective lots during the course of the experiments. In the case of the expeller soybean oil meal this was 16

percent as against 5.6 percent. In the case of the toasted solvent extracted soybean oil meal it was 9.1 percent as against 1.5 percent. Obviously, the rations containing soybean oil meal as the sole protein concentrate were deficient in one or more respects. In efforts at improving it for dry lot feeding a number of things were tried with a ration of yellow corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast. The next portion of the bulletin reports experiments of this nature.

VARIOUS METHODS OF IMPROVING RATION TRIED

Outer Hull Removed — Soybean Flour

Soybean flour was compared with soybean oil meal in one experiment. It differs from the meal in that it does not contain the outer hull of the bean. The flour used was made at a relatively low temperature. Like wheat flour, it was very fine and powdery in character. Part A of Table 10 summarizes the results from soybean flour and from soybean oil meal.

The pigs fed soybean flour did poorly. Consequently, after 12 weeks the feeding of the soybean flour as such was discontinued. Normally as pigs become heavier and fatter they require more feed per unit of gain. To make the data comparable, the summary for the group fed soybean oil meal is not for an equal length of time but to approximately the same average final weight as that for those fed soybean flour. The pigs fed soybean oil meal were as heavy after 8 weeks on feed as those fed soybean flour were after 12 weeks on feed. In these resepctive periods, the pigs fed soybean flour ate 14.6 percent less feed daily a head, gained 35.9 percent less rapidly, and required 34.0 percent more feed per unit of gain than those fed soybean oil meal.

After 12 weeks, the group fed soybean flour was divided. One section of the group was then fed soybean grits. The grits were obtained from the same source and were made in the same way as the flour. However, they were not powdery in form but were particles about the size of grains of wheat. The pigs in the other section of the group were continued on the soybean flour but, thereafter, before it was fed the flour was moistened, cooked for an hour with steam under pressure, dried, and reground.

The performance of the pigs fed the soybean grits was better than was that of the entire group during the first 12 weeks or while they received the soybean flour but was not equal to that of the pigs fed

Table 10.—Soybean Flour and Soybean Oil Meal as Protein Concentrates for Pigs in Dry Lot.

Started Dec. 5, 1944 Feeds mixed and self fed	Part A Before Lot 6 was changed		Part B After Lot 6 was changed		
	1 Corn **Soybean oil meal** Ground alfalfa Minerals	6 Corn **Soybean flour*** Ground alfalfa Minerals	1 Corn **Soybean oil meal** Ground alfalfa Minerals	6B Corn **Soybean grits** Ground alfalfa Minerals	6C Corn **Cooked soybean flour** Ground alfalfa Minerals
From	Dec. 5	Dec. 5	Jan. 30	Feb. 27	Feb. 27
To	Jan. 30	Feb. 27**	April 17	June 19	May 15
Pigs at start	15	15	15	6	6
Initial wt. per pig, lb.	52.1	52.7	95.6	91.6	95.9
Pigs at close	15	13	14	6	6
Final wt. per pig, lb.	95.6	92.6	209.0	205.6	208.7
Ave. daily gain, lb.	.78	.50	1.45	1.01	1.47
Daily feed per pig, lb:					
Corn	2.06	1.83	4.63	2.95	4.08
Soybean oil meal	.70		1.20		
Soybean flour		.50			.88
Soybean grits				.61	
Ground alfalfa	.12	.10	.25	.15	.22
Minerals	.06	.08	.13	.11	.16
Total	2.94	2.51	6.21	3.82	5.34
Feed per 100 lb. gain, lb.:					
Corn	264.58	369.73	319.43	290.24	278.55
Soybeal oil meal	90.71		82.53		
Soybean flour		101.30			60.20
Soybean grits				60.21	
Ground alfalfa	15.12	20.26	17.13	15.07	14.57
Minerals	7.56	15.20	9.24	11.30	10.93
Total	377.97	506.49	428.33	376.83	364.25
Cost of feed per 100 lb. gain	$ 9.86	$13.83	$11.01	$10.05	$ 9.74

* After 12 weeks the group was divided. Six of the pigs were then fed soybean grits and six soybean flour which had been moistened, cooked for one hour with steam under pressure, dried, and reground.

** Since normally as pigs become heavier and fatter they require more feed per unit of gain, the data for Lot 1 are to approximately the same final weight. Although both were started at an average weight of approximately 52 pounds, it took Lot 1 eight and Lot 6 twelve weeks to reach a weight of approximately 95 pounds.

Total pig days Lots 1 and 6 Part A, Lots 1, 6B, and 6C Part B, 840, 1204, 1092, 672, and 462, respectively. Total gain Lots 1 and 6 Part A, Lots 1, 6B, and 6C Part B, 652.833, 596.167, 1583.0, 682.0, and 677 pounds, respectively.

the cooked soybean flour. The pigs fed the cooked soybean flour gained at approximately the same rate as those fed soybean oil meal. They required less feed per unit of gain. Perhaps their lower feed requirement per unit of gain was due to their poor gains during the first 12 weeks and their relatively thin condition when they were started on the cooked soybean flour.

When they were made at relatively low temperatures, soybean oil meal and soybean flour, like raw soybeans, were unsatisfactory feeds for growing and fattening pigs. Whether the flour, the oil meal, or the bean itself was used, subjecting the product to a sufficiently high temperature to thoroughly cook it changed it from an unsatisfactory to a comparatively satisfactory high-protein feed for pigs from the standpoint of production.

Oil Content Reconstituted

Since cooked soybeans had given good performance in earlier experiments and since presumably the difference in oil content was the chief difference between them and good quality soybean oil meal, rations of corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast without and with the addition of soybean oil were compared in one experiment. The oil was added at the rate of three percent of the ration. This approximated the amount that would have been supplied if soybeans instead of the oil meal had been fed. Table 11 summarizes the results secured from the two rations.

The pigs fed the ration containing the soybean oil gained 4.9 percent more rapidly, were ready for market 7 days earlier and required 4.2 percent less feed per unit of gain than those without the oil. The two groups ate practically the same amounts of feed daily a head. When the rations were placed on an approximately equivalent energy basis by multiplying the added oil by 2.25, which is the difference in energy value between carbohydrates and fats, there was practically no difference in the amounts of feed required per unit of gain. As determined by the amounts of feed per unit of gain, replaced by it, and with feeds at the prices used, the feeding value of the oil in the ration was 2.35 times that of the soybean oil meal a pound.

Synthetic Methionine, an Essential Amino Acid, Added

Soybean oil meal is commonly considered one of the most effective protein supplements of plant origin. Nevertheless it seemed possible that a ration of corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast might be inadequate in one or more of the essential amino acids or nitrogenous units for the optimum growth and well being of pigs. Including synthetic d-l methionine, an essential amino

Table 11.—Effect of Feeding Soybean Oil with Soybean Oil Meal to Pigs.

Experiment started July 14, 1943 Feeds mixed and self fed	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Soybean oil meal** **Soybean oil** Ground alfalfa Minerals
Pigs at start	13	13
Initial weight per pig, lb.	54.5	55.5
Pigs at close	12	10
Final weight per pig, lb.	192.5	194.1
Average daily gain, lb.	**1.01**	**1.06**
Days to gain 160 pounds	159	152
Daily feed per pig, lb.:		
Corn	3.04	2.89
Soybean oil meal	.68	.72
Soybean oil		.12
Ground alfalfa	.16	.16
Minerals	.08	.08
Total	3.96	3.97
Feed per 100 lb. gain, lb.:		
Corn	302.12	273.79
Soybean oil meal	67.33	68.05
Soybean oil		11.29
Ground alfalfa	15.72	15.06
Minerals	7.86	8.28
Total	**393.03**	**376.47**
Feed per 100 lb. gain with added oil × 2.25		390.58
Cost of feed per 100 lb. gain	$ 9.99	$10.46

Lot 1, 77 lb. pig out on 70th day; Lot 2, 133 lb. pig out on 84th day; 109.5 lb. pig out on 98th day; and 178.5 lb. pig out on 112th day.

Total pig days, Lots 1 and 2, 1666 and 1554, respectively. Total gain Lots 1 and 2, 1678.5 and 1640.5 lb., respectively.

acid or protein fraction, in such a ration was tried in one experiment. The methionine was supplied through the courtesy and cooperation of the Ammonia Department, Chemical Division Experimental Station of the E. I. Du Pont de Nemours and Company. It was fed at the rate of 0.2 percent of the total ration, or at an average rate of 0.7 percent of the supplemental mixture. Table 12 summarizes the results secured.

Apparently as a result of illness, one pig in the d-l methionine group which gained satisfactorily during the first two weeks failed to gain during the next and so was removed on the 28th day. After it

Table 12.—Feeding Methionine with a Protein Concentrate of Soybean Oil Meal to Pigs in Dry Lot.

Started December 5, 1944 Feeds mixed and self fed	Part A Before dividing Lot 7		Part B After dividing Lot 7			Part C Entire time	
	1 Corn **Soybean oil meal** Ground alfalfa Minerals	7 Corn **Soybean oil meal Methionine** Ground alfalfa Minerals	1 Corn **Soybean oil meal** Ground alfalfa Minerals	7-B Corn **Soybean oil meal Methionine** Ground alfalfa Minerals	7-C Corn **Soybean oil meal Methionine** Ground alfalfa Minerals	1 Corn **Soybean oil meal** Ground alfalfa Minerals	7 Corn **Soybean oil meal Methionine** Ground alfalfa Minerals
From	Dec. 5	Dec. 5	Feb. 27	Feb. 27	Feb. 27	Dec. 5	Dec. 5
To	Feb. 27	Feb. 27	Apr 17	Apr. 10	Apr. 17	Apr. 10	Apr. 17
Pigs at start	15	15	14	9	4	15	15
Initial weight per pig, lb.	52.1	52.3	131.0	143.0	106.5	52 1	52.3
Pigs at close	14	13	14	8	4	14	12
Final weight per pig, lb.	131.0	131.8	209.0	207.7	157.0	199.3	198 0
Average daily gain, lb.	**0.92**	**0.93**	**1.59**	**1.52**	**1.03**	**1.14**	**1.09**
Days to gain 160 pounds						140	148
Daily feed per pig, lb.:							
Corn	2.53	2.73	5.29	5.13	3 88	3 39	3.45
Soybean oil meal	.83	.86	1 25	1 21	.91	96	.95
Methionine		.01		.01	.01		.01
Ground alfalfa	.15	.15	.30	.27	.21	.19	.19
Minerals	.07	.08	.15	.15	.11	10	10
Total	3.58	3.83	6 98	6 77	5.12	4 64	4 70
Feed per 100 lb. gain, lb.:							
Corn	275.79	291.59	332.22	336.73	376.75	296 35	317.52
Soybean oil meal	90.63	92.35	78.89	79 09	88.47	84 08	87.94
Methionine		.82		.87	.99		.87
Ground alfalfa	15.60	16.38	17.53	17.77	19.88	16.21	17.31
Minerals	7.90	8.36	9.64	9.77	10.94	8.54	9.16
Total	**389.92**	**409.50**	**438.28**	**444.24**	**497.03**	**405.18**	**432.79**
Cost of feed per 100 lb. gain	$10.15	$10.61	$11.22	$11.34	$12.69	$10 46	$11.14

Total pig days, Lots 1 and 7 Part A, Lots 1, 7B and 7C Part B, Lots 1 and 7 Part C, 1246, 1120, 686, 350, 196, 1822, and 1722, respectively. Total gain Lots 1 and 7 Part A, Lots 1, 7B and 7C Part B, Lots 1 and 7 Part C, 1144.333, 1047.0, 1092.0, 533.5, 202.0, 2099.833, and 1869.5 pounds, respectively.

was on feed for two weeks, another developed prolapsus ani. It was operated on but failed to recover properly and so was removed on the 42nd day. Still another pig in the group gained for 98 days and then ceased to gain. It was removed on the 112th day. A pig on the ration without the d-l methionine gained during the first five two-week periods but failed to gain during the next two-week period and so was removed. Although actually they were not taken out until later, these pigs were figured as removed at the time of their maximum weight. Since the amounts of feed consumed by them from the time of their heaviest weight to the time of their removal was not known, no feed was deducted to allow for what they ate in the meantime.

If it were assumed that in these periods from the time of their maximum weight to the time of their removal, the pigs removed from Lot 7 ate half as much feed as the others, and if these amounts were deducted, the feed required per 100 pounds of gain (1) by the group for the first 84 days, (2) by the pigs in the more rapid gaining section of the group for the remainder of the test and, (3) by the entire group for the entire time would have been 406, 451, and 430 pounds, respectively. These figures are not materially different from those without deductions given in Table 12.

During the first 12 weeks the pigs without and those with d-l methionine gained 0.92 and 0.93 pounds daily a head and required averages of 390 and 409 pounds of feed per 100 pounds of gain, respectively. On the 84th day four of the slower gaining pigs from the d-l methionine group were placed in a different pen but continued on the same ration.

For the entire time or until an average weight of approximately 200 pounds was reached the pigs without and those with d-l methionine gained 1.14 and 1.09 pounds daily a head and required 405 and 433 pounds of feed per 100 pounds of gain, respectively. The eight best doing pigs without and the eight best doing pigs with d-l methionine gained 1.33 and 1.25 pounds daily a head, respectively.

From the 84th day until they were discontinued, the group without d-l methionine gained 1.59 pounds daily a head and required 438 pounds of feed per 100 pounds of gain. In the same period the 8 more rapid gaining pigs with d-l methionine, that is those in Group 7-B, gained 1.56 pounds daily a head. The group required 444 pounds of feed per 100 pounds of gain.

There was no benefit from including d-l methionine in the ration.

Little or no scouring was encountered. Otherwise, although twice as much d-l methionine as Ferrin (5) feed was used, the results were in

accord with those obtained by Ferrin, who tried d-l methionine with a ration consisting of ground yellow corn, 70.4; dried whey, 2.5; dehydrated alfalfa leaf meal, 5.0; irradiated yeast (9,000 U.S.P. units D/gm), 0.02; iodized salt, 0.5; defluorinated rock phosphate, 1.9; toasted solvent extracted soybean oil meal, 19.6; plus 300 micrograms of riboflavin and three milligrams of niacin per 100 pounds of feed.

Oats Included in Ration

Ground oats were fed with yellow corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast in three experiments. If oats or other small grains were successful in improving a ration of this type for dry lot feeding, they would have an advantage over commercial products or by-products, particularly those the supply of which is limited and will remain limited regardless of the need or demand for them.

Table 13.—Oats With a Sole Protein Concentrate of Soybean Oil Meal for Pigs in Dry Lot.

Experiments conducted in 1943 and 1945 Feeds mixed. Pigs hand fed in one and self fed in two experiments	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Oats** **Soybean oil meal** Ground alfalfa Minerals
Number of comparisons	3	3
Pigs at start	41	41
Initial weight per pig, lb.	53.6	54.6
Pigs at close	34	38
Final weight per pig, lb.	202.7	201.7
Average daily gain, lb.	**1.05**	**1.14**
Days to gain 160 pounds	153	141
Daily feed per pig, lb.:		
Corn	3.09	2.59
Oats		.75
Soybean oil meal	.79	.75
Ground alfalfa	.16	.17
Minerals	.09	.08
Total	4.13	4.35
Feed per 100 lb. gain, lb.:		
Corn	294.20	227.29
Oats		66.22
Soybean oil meal	75.12	66.22
Ground alfalfa	15.41	14.88
Minerals	8.02	7.12
Total	**392.75**	**381.74**
Cost of feed per 100 lb. gain	$10.09	$ 9.81

Total pig days, Lots 1 and 2, 5236 and 5201, respectively.

Total gain, Lots 1 and 2, 5500.0 and 5927.667 pounds, respectively.

Oats and other small grains can be grown over an extensive area. Usually they could be grown rather than purchased. Their production could be increased with an increasing demand so that except possibly temporarily they would not be likely to become prohibitive in cost.

The ground oats were fed at the rate of a pound for each pound of soybean oil meal or 0.75 of a pound for each pound of supplement. This averaged a pound for every 3.43 pounds of corn or 17.35 percent of the total ration. A summary of the three experiments is presented in Table 13.

The pigs having the oats required 2.8 percent less feed per unit of gain and made faster gains so they were ready for market 12 days earlier, on the average, than those without oats. An average of approximately 30 percent of standard weight oats is hull. The hulls are of little worth for growing and fattening pigs. On a hull-deducted basis, the pigs having oats required 7.9 percent less feed per unit of gain than those without oats. With other feeds at the prices used each pound of ground oats fed saved 1.22 pounds of ground corn or its equivalent. Although the oats were beneficial, they failed to make the ration a fully adequate one. As they did on the same ration without the oats, some of the pigs became unthrifty, some became wrinkly and rough in the skin, and some developed a wheezy respiration.

Other Plant Protein Concentrates Fed With Soybean Oil Meal

Whether, when no animal protein concentrate is included in the ration, two or more high-protein feeds of plant origin will prove more effective than one is a pertinent question in the feeding of soybean oil meal. Part A of Table 14 summarizes three experiments in which a mixture of equal weights of soybean oil meal and cottonseed meal was compared with soybean oil meal alone for feeding with yellow corn, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot.

The cottonseed meal averaged 8.94 percent of the total ration. Cottonseed meal is considered reasonably safe for hogs if it is fed along with other high-protein feeds and does not exceed 10 percent of the total ration. In order to avoid any possible deleterious effect from the free-gossypol it contained, the cottonseed meal was treated with a solution of ferrous sulfate.

In one of the experiments the pigs fed the combination of soybean oil meal and cottonseed meal made more rapid gains and greater gains per unit of feed than those fed soybean oil meal as the only high-protein feed in the ration. In another they made slightly more rapid gains but less gain per unit of feed. In the third experiment they made less rapid gains and less gain per unit of feed than those fed a protein concentrate of soybean oil meal only. On the average, the pigs having

Table 14.—Feeding Other Plant Protein Concentrates with Soybean Oil Meal to Pigs in Dry Lot.

Experiments conducted: Part A, 1931, 1939, and 1941 Part B, 1943	Part A Iron treated cottonseed meal		Part B Linseed and iron treated cottonseed meal	
	1 Corn **Soybean meal** Ground alfalfa Minerals	2 Corn **Cottonseed meal*** **Soybean meal** Ground alfalfa Minerals	1 Corn **Soybean meal** Ground alfalfa Minerals	2 Corn **Linseed meal** **Cottonseed meal*** **Soybean meal** Ground alfalfa Minerals
Number of comparisons	3	3	2	2
Pigs at start	40	41	27	27
Initial weight per pig, lb.	55.4	55.3	54.5	55.1
Pigs at close	36	37	21	25
Final weight per pig, lb.	210.7	213.6	199.8	197.2
Average daily gain	**1.08**	**1.17**	**1.03**	**1.17**
Days to gain 160 pounds	149	137	156	137
Daily feed per pig, lb.:				
Corn	3.30	3.68	3.05	3.38
Linseed meal				.16
Cottonseed meal		.43		.16
Soybean oil meal	.73	.43	.73	.54
Ground alfalfa	.16	.18	.16	.18
Minerals	.11	.12	.08	.09
Total	4.30	4.84	4.02	4.51
Feed per 100 lb. gain, lb.:				
Corn	306.13	313.46	296.43	288.64
Linseed meal				13.65
Cottonseed meal		36.90		13.65
Soybean oil meal	68.34	36.90	70.98	46.02
Ground alfalfa	14.75	15.18	15.14	14.86
Minerals	9.94	10.16	7.81	8.03
Total	**399.16**	**412.60**	**390.36**	**384.85**
Cost of feed per 100 lb. gain	$10.29	$10.49	$ 9.96	$ 9.81

* To overcome any possible toxic effect from the free-gossypol, the cottonseed meal was treated with a solution of ferrous sulfate.

Good quality expeller soybean oil meal was fed in one and toasted solvent extracted soybean oil meal was fed in two of the experiments summarized in Part A. The extracted meal made up 74.1 percent of the total fed Lot 1, and 71.7 percent of the total fed Lot 2.

Good quality expeller soybean oil meal was fed in the experiments summarized in Part B.

Total pig days, Lots 1 and 2 Part A, Lots 1 and 2 Part B, 5215, 5145, 3318, and 3108, respectively. Total gain Lots 1 and 2 Part A, Lots 1 and 2 Part B, 5622.5, 6034.333, 3416.167, and 3639.833 pounds, respectively.

the mixture ate more feed daily a head, gained more rapidly, and were ready for market 12 days earlier but required more feed per unit of gain than those having only soybean oil meal as a protein concentrate.

At the prices used for other feeds and based solely on the amounts of these saved per unit of gain, the cottonseed meal showed an average worth of 65.4 percent that of good quality expeller soybean oil meal containing 41 percent of protein.

Part B of Table 14 summarizes two experiments in which mixtures of linseed, cottonseed meal, and soybean oil meal were compared with soybean oil meal alone for feeding with yellow corn, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot. In one trial the linseed, cottonseed meal, and soybean oil meal were fed in a 1:1:2 ratio. In the other, they were fed a ratio of 1:1:3. The averages were linseed, 18.6; cottonseed meal, 18.6; soybean oil meal, 62.8 percent. As when no linseed was included, the cottonseed meal was treated with a solution of ferrous sulfate to prevent any possible deleterious effect from the free-gossypol it contained.

The pigs fed the mixture ate 12.2 percent more feed daily a head, gained 13.7 percent more rapidly, were ready for market 19 days earlier, on the average, and required 2.2 percent less feed per unit of gain than those fed soybean oil meal as the only protein concentrate. With other feeds at the prices used and with only the amounts of feed per unit of gain considered, the mixture of equal weights of linseed and cottonseed meal was worth 12.3 percent more a pound than expeller or 41 percent protein soybean oil meal.

Like the inclusion of oats, the inclusion of a combination of linseed and cottonseed meal in the ration did not result in optimum growth or prevent the occurrence of unthriftiness or a tendency toward roughness of the skin, excessive fatness or impaired respiration in some of the pigs. No data to see whether a cumulative favorable effect from including both, other plant protein concentrates and oats in the ration were secured.

An Animal Protein Concentrate Fed With Soybean Oil Meal

A number of experiments were conducted in which soybean oil meal alone was compared with a mixture of soybean oil meal and an animal protein concentrate for feeding with corn, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot. Sixty percent protein meat scraps were used as the animal protein concentrate in eight of these comparisons. The results obtained from including some meat scraps in the ration are shown in Part A of Table 15. In one of the eight comparisons the meat scraps and soybean oil meal were fed in a 1:2 ratio. In the others equal weights of each were used.

The pigs given meat scraps ate 16.9 percent more feed daily a head, gained 20.6 percent more rapidly, were ready for market 25 days earlier, on the average, and required 2.5 percent less feed per unit of gain than those given a similar ration except for the meat scraps. They

Table 15.—Feeding an Animal Protein Concentrate with Soybean Oil Meal to Pigs in Dry Lot.

Experiments conducted: Part A, 1942 to 1946 Part B, 1940 to 1946	Part A		Part B	
	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Meat scraps Soybean oil meal** Ground alfalfa Minerals	1 Corn **Soybean oil meal*** Ground alfalfa Minerals	2 Corn **Fish meal Soybean oil meal*** Ground alfalfa Minerals
Number of comparisons	8	8	4	4
Pigs at start	109	106	56	56
Initial weight per pig, lb.	19.8	50.6	49.4	49 7
Pigs at close	93	92	49	54
Final weight per pig, lb.	205.0	212.6	206.3	207.4
Average daily gain, lb.	**1.07**	**1.29**	**1.13**	**1.35**
Days to gain 160 pounds	150	125	142	120
Daily feed per pig, lb.:				
Corn	3.09	3.87	3.29	4.11
Meat scraps		.37		
Fish meal				.40
Soybean oil meal	.84	.40	.90	.40
Ground alfalfa	.17	.20	.18	.21
Minerals	.09	.06	.10	.07
Total	4.19	4.90	4.47	5.19
Feed per 100 lb. gain, lb.:				
Corn	288.20	300.44	292.43	304.44
Meat scraps		28.89		
Fish meal				29.52
Soybean oil meal	78.10	30.67	79.77	29.52
Ground alfalfa	15.91	15.61	15.88	15.37
Minerals	8.10	4.97	8.73	5.39
Total	**390.31**	**380.58**	**396.81**	**384.24**
Cost of feed per 100 lb. gain	$10.05	$10.15	$10.27	$10.32

* Toasted solvent extracted soybean oil meal was used in one of the four experiments. This made up 24.3 percent of the total when it was fed without and 24.5 percent of the total when it was fed with fish meal. With this exception, expeller soybean oil meal was used in the experiments reported in Parts A and B of Table 15.

Total pig days Lots 1 and 2 Part A, Lots 1 and 2 Part B, 14,553, 12,110, 7,386, and 6,344, respectively. Total gain Lots 1 and A Part A, Lots 1 and 2 Part B, 15,605.0, 15,577.167, 8,329.0, and 8,565 pounds, respectively.

also grew and developed normally and showed no discernable evidences of malnutrition in any of the comparisons.

Part B of Table 15 summarizes 4 comparisons of soybean oil meal and a mixture of equal weights of fish meal and soybean oil meal as protein concentrates for feeding with corn, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot. The pigs fed the mixture took 16.1 percent more feed daily a head, gained 19.5 percent more rapidly, were ready for market 22 days earlier, on the average, and required 3.2 percent less feed per unit of gain than those fed soybean oil meal as the only protein concentrate. They grew and developed normally and showed no indication of malnutrition.

Using an animal protein concentrate in combination with it is a simple and effective method of improving soybean oil meal as a high protein feed for dry lot feeding. The data should not be interpreted as indicating that optimum performance will result from the single addition or that further improvements are impossible. If or when animal protein concentrates are scarce or relatively high in price, using them may not be the most feasible or the most economical method of improving the ration. Fortunately others are available so the feeder is not dependent on a single method of improvement but can choose the one which is likely to prove the most economical under a given set of conditions.

Ground Alfalfa Increased During Growing Period

In the experiments reported, ground alfalfa was commonly fed at the rate of 4 to 5 percent of the total ration. Usually it was purchased as hay and was then ground in a hammer mill as needed. In so far as possible, third cutting, fine-stemmed, green, leafy alfalfa hay of high quality was used. In a test in which 5 percent was fed to all groups, feeding an additional 10 percent to one group until it averaged approximately 120 pounds in weight and 5 percent thereafter was tried. A commercial meal made from whole, sun-cured alfalfa was fed in this particular experiment. Although an effort was made to obtain a good product, that secured was of poorer quality than was the alfalfa used in the other experiments. It was sold to contain 15 percent of protein. It contained 11.7 percent of protein, 31.0 percent of fiber, and 9,450 U.S.P. units of vitamin A, and 6.49 milligrams of riboflavin to the pound. Table 16 gives the results secured.

The pigs having a relatively large quantity of alfalfa during the growing and a small quantity during the fattening period gained at

practically the same average rate and required 3 percent more feed per pound of gain than those having a small quantity for the entire time.

Some of the pigs in each group reached a point at which they ceased to gain or began losing weight and so were removed from their respective lots. In summarizing the data these were figured as removed at the time of their maximum weight on a regular by-weekly weigh day or on the same day of an intervening week. Since the amount was not known, no feed was deducted to allow for that consumed by them from the time of their maximum weight to the time of their actual removal.

Table 16.—Additional Ground Alfalfa During Growing Period; and Legume Silage When Soybean Oil Meal Is Used as the Protein Concentrate (Entire Time).

Experiment started: December 14, 1943	1	2	3
	Corn	Corn	Corn
	Soybean oil meal	**Soybean oil meal**	**Soybean oil meal**
		Additional ground alfalfa*	**Legume silage†**
Feeds mixed and self fed	Ground alfalfa		Ground alfalfa
	Minerals	Minerals	Minerals
Pigs at start	14	14	14
Initial weight per pig, lb.	54.6	54.9	55.0
Pigs at close	9	11	10
Final weight per pig, lb.	220.9	220.8	209.6
Average daily gain, lb.	**1.07**	**1.09**	**1.09**
Days to gain 160 pounds	150	147	147
Daily feed per pig, lb.			
Corn	3.15	3.18	3.05
Soybean oil meal	.80	.81	.77
Legume silage			.08
Ground alfalfa	.16	.35	.15
Minerals	.08	.08	.08
Total	4.19	4.42	4.05+
Feed per 100 lb. gain, lb.:			
Corn	295.32	291.05	278.82
Soybean oil meal	74.34	73.95	70.45
Legume silage			7.61
Ground alfalfa	14.81	32.31	14.07
Minerals	7.85	7.25	7.42
Total	**392.32**	**404.56**	**370.76+**
Cost of feed per 100 lb. gain	$10.07	$10.29	$ 9.54

† Fed ad lib.

* Fifteen instead of five percent of ground alfalfa fed until group averaged 125 pounds in weight.

\+ Not including the legume silage. The silage was a mixture of clover and alfalfa. Total pig days, Lots 1, 2, and 3, 1722, 1918, and 1806, respectively. Total gain, Lots 1, 2, and 3, 1,838.667, 2,096.0, and 1,972.167 pounds, respectively.

Considering only the pigs that remained in each lot at the close of the test, the pigs fed 5 percent of alfalfa for the entire time and the pigs fed 15 percent during the growing and 5 percent during the fattening period made average daily gains for the entire time of 1.16 and 1.18 pounds, respectively.

The data for the growing and the fattening periods are presented in Parts A and B of Table 17, respectively. During the growing period the pigs fed 15 percent of ground alfalfa gained 3 percent less rapidly and required 16.1 percent more feed per unit of gain than those fed 5 percent of alfalfa. During the fattening period, although both lots then received the same ration, the pigs that earlier had received 15 percent of alfalfa gained 7 percent faster and required 5.7 percent less feed per 100 pounds of gain than those that earlier had received 5 percent of alfalfa. Doubtless their thinner condition at the beginning of the fattening period was partially responsible for the better showing made by the pigs previously having the higher level of alfalfa. Thin pigs gain faster and require less feed per unit of gain than fatter ones of similar weight. Possibly a greater ingestion and storage of vitamins during the growing period was another factor involved.

Good quality alfalfa and other leguminous hays have a number of characteristics which make them benificial for feeding in limited quantities with corn or other grains to pigs in dry lot. They are much higher in minerals, particularly calcium, than are the grains. They contain a higher percentage of protein. Furthermore, the proteins in them are relatively high in some of the essential amino acids or protein fractions in which the grains are low. Good quality leguminous hay is an excellent source of carotene or vitamin A. This is of less importance when yellow corn is fed than when white corn or other grains are used. When the hay is sun-cured it supplies some vitamin D. However, vitamin D, or its equivalent, can easily be supplied in other ways, such as by exposure to sunlight or through the use of a very small quantity of irradiated yeast or irradiated ergosterol. Good quality leguminous hay is also beneficial as a source of B-complex or water soluble vitamins. Perhaps this is the most important contribution made by alfalfa to a dry lot ration. The amounts of the various needed nutrients supplied by leguminous hay depend on its quality and on the quantity included in the ration. Fairbanks, Krider, and Carroll (4) found that the addition of 10 percent of ground dehydrated alfalfa to a basal ration of yellow corn, 59.0; wheat middlings, 15.0; soybean oil meal, 12.5; tankage, 8; fish meal, 3.5; fortified cod liver oil, 0.5; iodized salt, 0.5; limestone, 0.5; and bone meal, 0.5, which otherwise was inadequate for pigs in dry lot, enabled the pigs to thrive and to develop normally.

Table 17.—Additional Ground Alfalfa During Growing Period; and Legume Silage When Soybean Oil Meal Is Used as the Protein Concentrate.

	Growing Period			Fattening Period		
	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Soybean oil meal** **Additional** Ground alfalfa Minerals	3 Corn **Soybean oil meal** **Legume silage** Ground alfalfa Minerals	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Soybean oil meal** Ground alfalfa Minerals*	3 Corn **Soybean oil meal** **Legume silage** Ground alfalfa Minerals
Pigs at start	14	14	14	13	14	14
Initial weight per pig, lb.	54.6	54.9	55.0	127.7	122.3	119.5
Pigs at close	14	14	14	9	11	10
Final weight per pig, lb.	116.7	122.3	119.5	220.9	220.8	209.6
Average daily gain, lb.	**.99**	**.96**	**1.02**	**1.15**	**1.23**	**1.16**
Daily feed per pig, lb.:						
Corn	2.24	2.27	2.32	4.12	4.14	3.74
Soybean oil meal	.71	.74	.74	.88	.88	.80
Legume silage			.08			.09
Ground alfalfa	.16	.54	.16	.16	.16	.14
Minerals	.06	.05	.07	.10	.10	.10
Total	3.17	3.60	3.29+	5.26	5.28	4.77+
Feed per 100 lb. gain, lb.:				357.24	337.00	323.09
Corn	226.48	235.02	266.48	76.19	71.88	68.91
Soybean oil meal	72.28	76.48	72.28			7.58
Legume silage			7.64			
Ground alfalfa	16.06	55.96	16.06	13.69	12.91	12.38
Minerals	6.43	5.60	6.43	9.13	8.61	8.25
Total	**321.25**	**373.05**	**321.25+**	**456.25**	**430.40**	**412.63+**
Cost of feed per 100 lb. gain	$ 8.33	$ 9.45	$ 8.35	$11.64	$10.98	$10.55

* Fed additional ground alfalfa during the growing period but the same as Lot 1 during the fattening period.

\+ Not including the legume silage.

Commercial sun-cured alfalfa meal was used. It contained 11.75 percent of protein, 30.97 percent of fiber, 9,450 units of vitamin A per pound, and 14.3 units of riboflavin per gm. It was rather brown in color and, as the protein analysis indicates, rather stemmy in character.

A disadvantage of large quantities of leguminous hay for growing and fattening pigs is that hay is relatively high in fiber. As the fiber in the ration increases the rapidity of the gains and the gains per unit of feed, exclusive of the fiber, decrease. In a test in which ground alfalfa was used to vary the fiber, Vestal (24) fed pigs, started at 95 pounds, rations containing 2, 5, 7.5, and 10 percent of fiber. The groups as named gained 2.42, 2.31, 2.19, and 1.53 pounds daily a head and required 391, 397, 401, and 509 pounds of feed, on a fiber-free basis, for each 100 pounds of gain produced. In a test with pigs started at an average weight of approximately 50 pounds, Robison (19) used peanut hulls to vary the fiber content and fed rations containing 0.75, 3.0, 6, and 9 percent of fiber. The groups as named gained 1.53, 1.43, 1.25, and 1.22 pounds daily a head and, on a fiber-free basis, required 336, 361, 395, and 407 pounds of feed per 100 pounds of gain, respectively. Oat hulls were also used as sources of fiber by both investigators with similar results. Ellis, Zeller, and King (3) fed growing and fattening pigs rations containing 0, 5, 10, 15, and 20 percent of ground alfalfa. Beyond the 5 percent level, as the percentage of ground alfalfa in the ration increased, both the rapidity of the gains and the gains per unit of feed decreased.

Usually a relatively high level of vitamins and minerals in alfalfa or other leguminous hay is associated with a low fiber and a high protein content. These are the characteristics which make the hay of value for pigs. Alfalfa hay of average quality contains approximately 15 percent of protein and 29 percent of fiber. Whether that higher in fiber and lower in protein than the average is of sufficient worth to justify its use for pigs is questionable. Feeding low grade leguminous hay tends to defeat the purpose for which the hay is used.

Swine producers who grow some alfalfa or other leguminous hay and who save some of high quality from the second or third cutting for their pigs can convert corn, soybean oil meal, and minerals into an effective ration for dry lot feeding. Possibly a ration of this kind containing enough good leguminous hay to provide ample quantities of the various nutrients required would be too high in fiber to result in the maximum rate of gain. Although leguminous hay is beneficial for pigs in dry lot it is not needed by pigs having plenty of good pasture.

Legume Silage Provided

Legume silage is sometimes available or could be made available for pigs. Feeding legume silage in place of all of the ground alfalfa was not tried. However, in the test reported in Tables 16 and 17 one group of pigs was fed the basal ration which contained 5 percent of

dry alfalfa and besides was given whatever legume silage they cared for. The silage was made from a mixture of medium red clover and alfalfa. Since silage is high in moisture, it was not mixed with the other feed but was kept before the pigs in a trough. The dry feed was self fed.

The pigs having access to it ate only 0.08 pound of legume silage daily a head. During the growing period there was practically no difference in either the rapidity of the gains or the amount of gain per unit of feed between the pigs having and those not having access to legume silage. During the fattening period the two groups continued to gain at practically the same rate. However, with the silage included and converted to an equivalent moisture basis, those having access to it required 8.9 percent less feed per 100 pounds of gain than those having no legume silage. That so small a quantity of silage was solely or largely responsible for the difference seems doubtful.

Legume silage was eaten readily by sows during the winter gestation period. They were not full fed. By limiting their feed, growing and fattening pigs could be kept hungry and probably made to consume reasonable quantities of legume silage. Apparently, however, full fed growing and fattening pigs which do not need it to satisfy their appetites will not eat more than a very limited quantity of legume silage of their own volition. If some plan of forcing self or full fed pigs to take larger quantities of legume silage than they will consume of their own accord could be worked out the silage would be expected to have a beneficial effect and to be a satisfactory substitute for dry ground alfalfa in the ration.

Dried Brewers' Yeast, or B Complex Rich Material Added to Ration

Yeast is rich in water soluble vitamins or vitamins of the B complex. Dried brewers' yeast was fed at the rate of 1.5 percent of the total feed or an average of 6.6 percent of the supplemental mixture in one experiment. The various groups of pigs in the experiment were hand fed or were given what feed they would clean up readily twice daily. Part A of Table 18 gives the results secured.

The pigs having 1.5 percent of dried brewers' yeast in their ration gained very little faster and required practically the same amount of feed per 100 pounds of gain as pigs having the same ration without the yeast.

In two other trials dried brewers' yeast was fed at the rate of 2 percent of the total feed. This averaged 7.8 percent of the supplemental mixture. The pigs were self fed. Part B of Table 18 summarizes the results of the two trials.

Table 18.—Dried Brewers' Yeast With a Protein Concentrate of Soybean Oil Meal.

Experiments conducted: Part A, 1943; pigs hand fed Part B, 1943 and 1945; pigs self fed	Part A Dried brewers' yeast, 1.5 percent		Part B Dried brewers' yeast, 2.0 percent		
	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Dried brewers' yeast** **Soybean oil meal** Ground alfalfa Minerals	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Dried brewers' yeast** **Soybean oil meal** Ground alfalfa Minerals	3 Corn **Meat scraps** **Soybean oil meal** Ground alfalfa Minerals
	Hand fed		Self fed		
Number of comparisons	1	1	2	2	2
Pigs at start	13	13	28	28	28
Initial weight per pig, lb.	54.5	55.5	53.2	54.1	54.4
Pigs at close	12	13	22	25	27
Final weight per pig, lb.	204.2	204.8	212.9	212.7	213.0
Average daily gain, lb.	**1.04**	**1.07**	**1.08**	**1.20**	**1.32**
Days to gain 160 pounds	154	150	149	134	122
Daily feed per pig, lb.:					
Corn	3.14	3.21	3.15	3.37	3.97
Dried brewers' yeast		.06		.09	
Meat scraps, 60 percent					.38
Soybean oil meal	.69	.64	.84	.80	.38
Ground alfalfa	.16	.17	.17	.17	.19
Minerals	.08	.08	.09	.09	.07
Total	4.07	4.16	4.25	4.52	4.99
Feed per 100 lb. gain, lb.:					
Corn	301.62	301.04	292.78	280.86	300.94
Dried brewers' yeast		5.85		7.55	
Meat scraps, 60 percent					28.55
Soybean oil meal	66.53	59.84	78.35	66.53	28.55
Ground alfalfa	15.67	15.61	15.37	14.61	14.73
Minerals	7.83	7.80	8.13	7.77	4.97
Total	**391.65**	**390.14**	**394.63**	**377.32**	**377.74**
Cost of feed per 100 lb. gain	$ 9.98	$10.34	$10.16	$10.05	$10.05

Total pig days, Lots 1 and 2 Part A, Lots 1, 2, and 3 Part B, 1750, 1820, 3640, 3542, and 3311, respectively. Total gain, Lots 1 and 2 Part A, Lots 1, 2, and 3 Part B, 1819.5, 1940.833, 3922.5, 4246.0, and 4373.833 pounds, respectively.

In the two experiments the pigs fed the dried brewers' yeast ate 6.4 percent more feed daily a head, gained 11.1 percent faster, were ready for market 15 days earlier and required 4.4 percent less feed per unit of gain than those fed the same ration without the yeast. Fewer of the pigs fed yeast were removed from the lots because of ceasing to thrive. The ration was definitely improved by the addition of the dried brewers' yeast.

Without the support of further work, probably too much emphasis should not be placed on the differences in results from feeding dried brewers' yeast at the 1.5 and 2.0 percent levels in different experiments. Factors other than the percentage of yeast, such as differences in the storage of water soluble vitamins in the bodies of the pigs at the beginning of the tests could have been partially or wholly responsible for the differences secured.

The pigs having dried brewers' yeast with a protein concentrate of soybean oil meal in a ration otherwise made up of yellow corn, ground alfalfa, minerals, and a minute quantity of irradiated yeast to supply vitamin D made as much gain per unit of feed but gained less rapidly and were not ready for market until 12 days later than pigs fed a protein concentrate composed of equal weights of soybean oil meal and 60 percent protein meat scraps.

Yeast Grown in Feed, After Water is Added

Adding water and growing yeast in the wet feed was tried in six experiments. Since it was necessary to feed the wet feed in a trough, all of the groups in the first experiment were hand fed or given what feed they would clean up readily twice daily. This was the same experiment in which 1.5 percent of dried brewers' yeast was included in the ration for one group.

At the start of the tests, a three-cent cake of yeast was obtained from the grocery. Half was crumbled and stirred in the wet feed to be fed in the evening feed 24 hours later and half in the succeeding or morning feed. After the start and after water was added to the new feed some of the wet mash was poured from the feed for one time into that to be used 24 hours later. Thus, some of the growing or live yeast was transferred from the feed for one day to that for the next. In winter or when the weather was cool it was necessary to keep the wet feed in a heated room or at a temperature which permitted the yeast to grow.

Usually the culture was renewed with a fresh cake of yeast approximately once a month. Whether the yeast was growing was indicated by the carbon dioxide bubbles given off, by the fluffing up of the feed and

by the smell of the growing yeast. The pigs were carried from approximately 50 to 210 pounds in weight.

In the experiment in which the pigs were given what feed they would clean up readily twice daily, those having the wet feed containing the growing yeast ate 6.1 percent more feed daily a head, weighed dry, gained 8.7 percent more rapidly, were ready for market 12 days earlier and required 2.2 percent less feed per unit of gain than those given the same feed dry and without the yeast. The results of the test are given in Part A of Table 19.

In the other five experiments the groups getting the wet feed containing the growing yeast were full fed twice daily but the other groups were self fed. Nevertheless in each of the five trials without exception the pigs on the wet feed containing the growing yeast made faster gains and greater gains per unit of feed than those on the dry feed without the yeast. The results are summarized in Part B of Table 19.

The pigs given the wet feed containing the growing yeast ate 2.7 percent more feed daily a head, gained 12.4 percent more rapidly, were ready for market 16 days earlier and required 8.9 percent less feed per unit of gain, on the average, than the pigs self fed the same ration dry and without the yeast.

The pigs on the wet feed containing the growing yeast grew normally and showed no evidence of a deficiency in their ration. Thirteen out of 82 or 15.9 percent of those on the dry feed and three out of 82 or 3.7 percent of those on the wet feed containing the growing yeast were removed during the course of the experiments because they had ceased to gain or were losing weight. Two others in a group receiving yeast were removed. One of these developed pneumonia early in the experiment. The second one developed prolapsus ani.

The plan of growing yeast in the wet feed changed a mixture of yellow corn, soybean oil meal, ground alfalfa, minerals, and a minute quantity of irradiated yeast for vitamin D from an inadequate to an effective ration for dry lot feeding. It is not adapted to a self feeding program but could often be used to advantage by those who feed their pigs twice daily. The cost is negligible and under these conditions little or no extra work would be involved. If ear corn were fed, probably some carbonaceous feed would need to be mixed with the supplement in order to provide a suitable medium for the growing yeast. Some ground oats, some wheat middlings, or a small amount of ground shelled corn could be used for this purpose.

Condensed Fish Solubles Incorporated in Ration

Condensed fish solubles is the semi-solid product left after a portion of the water has been evaporated from the liquid material resulting

Table 19.—Adding Water and Growing Yeast in the Wet Feed When Soybean Oil Meal Is Used as the Protein Concentrate.

Experiments conducted: Part A, 1943 Part B, 1943 to 1946	Part A Dry feed hand fed		Part B Dry feed self fed		
	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Soybean oil meal** Ground alfalfa Minerals **Growing yeast**	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Soybean oil meal** Ground alfalfa Minerals **Growing yeast**	3 Corn **Meat scraps Soybean oil meal** Ground alfalfa Minerals
	Hand fed	Hand fed	Self fed	Hand fed	Self fed
Number of comparisons	1	1	5	5	5
Pigs at start	13	13	69	69	67
Initial weight per pig, lb.	54.5	55.7	51 6	51.0	52.6
Pigs at close	12	12	57	65*	62
Final weight per pig, lb.	204.2	203.5	206 6	210 3	211 2
Average daily gain, lb.	**1.04**	**1.13**	**1.13**	**1.27**	**1.36**
Days to gain 160 pounds	154	142	142	126	118
Daily feed per pig, lb.:					
Corn	3.14	3.32	3.28	3 37	4.01
Meat scraps					.40
Soybean oil meal	.69	.74	.92	.94	.40
Ground alfalfa	.16	.17	.18	.18	.20
Minerals	.08	.09	.09	.10	.07
Total	4.07	4.32	4.47	4.59	5.08
Feed per 100 lb. gain, lb.:					
Corn	301.62	294.56	291 30	265 63	294.55
Meat scraps					29.41
Soybean oil meal	66.53	65.51	81.27	73.73	29.41
Ground alfalfa	15.67	15.32	15 70	14 32	14.75
Minerals	7.83	7.66	8.29	7.56	4.83
Total	**391.65**	**383.05**	**396.56**	**361.23**	**372.95**
Cost of feed per 100 lb. gain	$ 9.98	$ 9.78	$10.23	$ 9.32	$ 9.97

* One of these removed because of prolapsus ani, and another because of pneumonia, which developed early in the experiment.

Total pig days, Lots 1 and 2 Part A, Lots, 1, 2, and 3 Part B, 1750, 1582, 8729, 8274, and 7476, respectively. Total gain, Lots 1 and 2 Part A, Lots 1, 2, and 3 Part B, 1819.5, 1783.833, 9843.0, 10505.167, and 10192.0 lb., respectively.

from the removal of oil from fish, fish cuttings or fish waste by means of hydraulic presses. Protein makes up approximately 30 and the entire dry matter or solids approximately 50 percent of the weight of condensed fish solubles. This is equivalent to a protein content of 52 percent on a 10 percent moisture basis. Condensed fish solubles is fed primarily as a source of water soluble or B complex vitamins. It contains vitamin B_{12}, APF or the animal protein factor, is high in riboflavin, pantothenic acid, and choline and is especially high in niacin. As with other feeds, the amounts of water soluble vitamins present vary in different samples from the same source and in supplies from different sources.

In a trial reported in Part A of Table 20, condensed fish solubles were fed at the rate of one pound to each 8 pounds of soybean oil meal. This averaged 8.64 percent of the supplement and 2.43 percent of the total feed. The pigs having the condensed fish solubles at this rate did better than those on the same ration without the fish solubles but not as well as pigs without fish solubles fed a protein concentrate consisting of equal weights of soybean oil meal and 60 percent protein meat scraps. They ate 15.3 percent more feed daily a head, gained 15.6 percent more rapidly and were ready for market 21 days earlier but required within 0.7 percent as much feed per unit of gain as the pigs on the same ration without the condensed fish solubles. On the other hand, they ate 3.3 percent less feed daily a head, gained 6.7 percent less rapidly, were ready for market 8 days later and required 3.5 percent more feed per unit of gain than the pigs without fish solubles and having a protein concentrate consisting of equal weights of soybean oil meal and 60 percent protein meat scraps.

Part B of Table 20 summarizes the results of two experiments in which condensed fish solubles were fed at the rate of one pound to each 5 pounds of soybean oil meal. This averaged 13 percent of the supplement or 3.7 percent of the total feed.

As indicated by a smaller number of pigs removed because they ceased to thrive, by more feed consumed daily a head, by faster gains and by greater gains per unit of feed consumed, including condensed fish solubles in the ration improved it materially.

The pigs fed the condensed fish solubles and soybean oil meal in the 1:5 ratio did practically as well as the pigs fed soybean oil meal and 60 percent protein meat scraps in a 1:1 ratio. They ate 3.3 percent more feed daily a head, gained 2.2 percent more rapidly and were ready for market 2 days earlier but took 1.5 percent more feed per unit of gain. These differences were small. Since the slightly faster gains of one group tended to offset the slightly lower feed requirement per unit of gain of the other they were regarded as inconsequential.

Table 20.—Condensed Fish Solubles with a Protein Concentrate of Soybean Oil Meal.

Experiments conducted: Part A, started Dec. 4, 1945 Part B, started Dec. 5, 1944 and July 2, 1946	Part A Ratio of fish solubles to soybean oil meal, 1:8			Part B Ratio fish solubles to soybean oil meal, 1:5		
	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Condensed fish solubles** **Soybean oil meal** Ground alfalfa Minerals	3 Corn **Meat scraps** **Soybean oil meal** Ground alfalfa Minerals	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Condensed fish solubles** **Soybean oil meal** Ground alfalfa Minerals	3 Corn **Meat scraps** **Soybean oil meal** Ground alfalfa Minerals
Number of comparisons	1	1	1	2	2	2
Pigs at start	14	14	14	28	28	26
Initial weight per pig, lb.	51.9	51.7	53.0	52.1	52.3	53.2
Pigs at close	13	12	13	23	26	22
Final weight per pig, lb.	207.4	214.0	216.7	208 4	210.7	211.7
Average daily gain, lb.	**1.09**	**1.26**	**1.35**	**1.18**	**1.41**	**1.38**
Days to gain 160 pounds	148	127	119	136	114	116
Daily feed per pig, lb.:						
Corn	3.16	3.57	4.05	3.40	3.81	4.04
Tankage			.41			.41
Condensed fish solubles		.12			.19	
Soybean oil meal	.89	.97	.41	.96	.98	.41
Ground alfalfa	.17	.20	.20	.18	.21	.21
Minerals	.09	.11	.07	.10	.12	.07
Total	4.31	4.97	5.14	4.64	5.31	5.14
Feed per 100 lb. gain, lb.:						
Corn	290.53	283.17	299.89	288.99	270 26	292.30
Tankage			30.15			29.67
Condensed fish solubles		9.56			13.85	
Soybean oil meal	81.90	76.50	30.15	81.30	69.25	29.67
Ground alfalfa	15.87	15.76	15.22	15.77	15.08	14.85
Minerals	8.37	8.87	5.07	8.53	8.52	4.90
Total	**396.67**	**393.86**	**380.49**	**394.39**	**376.96**	**371.39**
Cost of feed per 100 lb. gain	$10.35	$10.38	$10.17	$10.18	$10.02	$ 9.94
Fish solubles in supplement, percent		8.64			12.98	
Fish solubles in ration, percent		2.43			3.67	

Total pig days, Lots 1, 2, and 3 Part A, Lots 1, 2, and 3 Part B, 1918, 1624, 1645, 3479, 2940, and 2709, respectively. Total gain, Lots 1, 2, and 3 Part A, Lots 1, 2, and 3 Part B, 2083.833, 2047.667, 2220.833, 4090.333, 4139.833, and 3746.5, pounds, respectively.

An adequate quantity of condensed fish solubles made the mixture of yellow corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast an effective ration for dry lot feeding. Condensed fish solubles can often be used to advantage by manufacturers of commercial feeds. Since it is ill smelling and since it is a soupy product which in small quantities would need to be shipped in drums and since it would be difficult to mix with other feeds without equipment, it is not particularly suitable for use in farm mixed supplements.

Dried Distillers' Grain Solubles Included

Dried distillers' grain solubles are a product obtained from distilling alcohol from grain for beverage or for industrial purposes. In distilling procedures water is added to ground grain and the resulting slurry is pressure cooked. After the cooked mash has cooled, barley malt is added. The enzymes of the malt convert the starches of the grain into sugars. After further cooling the material is placed in fermentation vats, converted to the desired acidity and "set" with propagated yeast. In the fermentation process the growing yeast converts the sugars into alcohol. The fermented slurry is run into "wells" from which it is pumped to still towers where the alcohol and other volatile constituents are distilled off. What remains is called "whole stillage."

"Whole stillage" contains from 5 to 7 percent of solids or dry matter. It is passed over screens to remove the coarse grain particles, which, when pressed and dried, are known as distillers' dried grains or distillers' light grains. The resulting solution which still contains the soluble material and the fine particles in suspension that have passed through the screens is known as "thin stillage."

In some instances the thin stillage is centrifuged to remove more of the suspended material than is taken out by the screens. With or without this step the thin stillage is next evaporated under vacuum to a semi-solid syrup. If the thin stillage is centrifuged before evaporation, the semi-solid product contains approximately 45 percent of solids. If it is not, the semi-solid product contains approximately 30 percent of solids.

Semi-solid solubles may be mixed with the material that has been screened or both screened and centrifuged off and the mixture dried to form dried distillers' grains with solubles or distillers' dark grains; or they may be dried separately to form dried distillers' grain solubles. Dried distillers' grains with solubles can also be produced by mixing dried distillers' grain solubles with distillers' light grains.

Dried distillers' grain solubles are higher in minerals and are much lower in fiber than are dried distillers' grains. They are rich in a number

Table 21.—Dried Distillers' Grain Solubles with a Protein Concentrate of Soybean Oil Meal.

Experiments started: December 4, 1945, July 2, 1946, and December 3, 1946	1 Corn **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Dried distillers' grain solubles** **Soybean oil meal** Ground alfalfa Minerals	3 Corn **Meat scraps** **Soybean oil meal** Ground alfalfa Minerals
Number of comparisons	4	4	4
Pigs at start	55	55	53
Initial weight per pig, lb.	49.4	49.6	50.0
Pigs at close	47	50	49
Final weight per pig, lb.	211.4	210.6	214.9
Average daily gain, lb.	**1.11**	**1.34**	**1.35**
Days to gain 160 pounds	144	120	119
Daily feed per pig, lb.:			
Corn	3.17	3.55	3.98
Dried distillers' solubles		.30	
Tankage			.40
Soybean oil meal	.87	.87	.40
Ground alfalfa	.17	.20	.20
Minerals	.10	.10	.07
Total	4.31	5.02	5.05
Feed per 100 lb. gain, lb.:			
Corn	285.15	265.42	295.54
Dried distillers' solubles		22.48	
Tankage			29.80
Soybean oil meal	78.23	64.67	29.80
Ground alfalfa	15.49	15.00	15.01
Minerals	8.38	7.53	4.91
Total	**387.25**	**375.10**	**375.06**
Cost of feed per 100 lb. gain	$10.03	$10.03	$10.05

Total pig days, Lots 1, 2, and 3, 7385, 6222, and 6188, respectively.
Total gain, Lots 1, 2, and 3, 8210.333, 8324.333, and 8339.667, lb., respectively.

of the water soluble vitamins or those of the B complex. They are deficient in the same essential amino acids or protein fractions as are the grains from which they are derived.

Four dry lot comparisons of rations of yellow corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast without and with dried distillers' solubles included in them and also of a third ration which was similar to the first except that the protein concentrate in

it consisted of equal weights of 60 percent protein meat scraps and soybean oil meal were made. In two of the comparisons the dried distillers' grain solubles made up a fifth of the supplemental mixture. In two they were fed at the rate of 6 percent of the total feed. In the four they averaged 20.5 percent of the supplemental mixture and 6 percent of the total feed. Expeller soybean oil meal was used in three and toasted solvent extracted soybean oil meal in one of the comparisons. A summary of the results secured are presented in Table 21.

The pigs fed dried distillers' grain solubles remained healthier, ate 16.5 percent more feed daily a head, gained 20.7 percent more rapidly, were ready for market 24 days earlier and required 3.1 percent less feed per 100 pounds of gain, on the average, than those fed the same ration without the dried distillers' grain solubles.

Feeding 60 percent protein meat scraps at the same rate as the soybean oil meal in one case and including dried distillers' grain solubles in the ration in another were equally effective in improving the corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast ration for pigs in dry lot. There were practically no differences in the results secured from the two rations, so far as the feed consumed, the health and well-being of the pigs, the rapidity of the gains, or the gains per unit of feed consumed were concerned.

Animal Protein Feed and Distillers' Solubles Included

Since dried distillers' grain solubles and 60 percent protein meat scraps each improved the ration, whether a combination of the two would bring about a still further improvement was an interesting question. During the winter of 1947-1948 an experiment was conducted in which a ration of yellow corn, dried distillers' grain solubles, soybean oil meal, ground alfalfa, minerals, and irradiated yeast was compared with a similar ration except that in it the protein concentrate consisted of equal weights of 60 percent protein meat scraps and soybean oil meal. Table 22 summarizes the results secured.

The pigs having both meat scraps and dried distillers' grain solubles ate 11.8 percent more feed daily a head, gained 15.4 percent more rapidly, were ready for market 18 days earlier and required 3.9 percent less feed per unit of gain than those having only the dried distillers' grain solubles included in the ration.

In an experiment conducted during the winter of 1948-1949 one group of pigs was fed a basal ration of yellow corn, dried distillers' grain solubles, soybean oil meal, ground alfalfa, minerals, and irradiated yeast. Another group was fed the same ration except for the protein concentrate. It consisted of a mixture of 60 percent protein meat scraps

Table 22.—Meat Scraps with Soybean Oil Meal when Dried Distillers' Grain Solubles Are Included in the Ration.

Started December 2, 1947 Feeds mixed and self fed	1 Corn **Dried distillers' grain solubles** **Soybean oil meal** Ground alfalfa Minerals	2 Corn **Dried distillers' grain solubles** **Meat scraps** **Soybean oil meal** Ground alfalfa Minerals
Pigs at start	14	14
Initial weight per pig, lb.	51.9	52.7
Pigs at close	14	13
Final weight per pig, lb.	214.8	213.3
Average daily gain, lb.	1.23	1.12
Days to gain 160 pounds	131	113
Daily feed per pig, lb.:		
Corn	3.36	3.92
Dried distillers' solubles	.23	.25
Meat scraps		.30
Soybean oil meal	.74	.40
Ground alfalfa	.23	.26
Minerals	.09	.06
Total	4.65	5.20
Feed per 100 lb. gain, lb.:		
Corn	274.60	275.25
Dried distillers' solubles	18.98	18.24
Meat scraps		20.77
Soybean oil meal	60.14	27.78
Ground alfalfa	18.98	18.24
Minerals	6.95	4.45
Total	**379.65**	**364.73**
Cost of feed per 100 lb. gain	$ 9.97	$ 9.85

Total pig days, Lots 1 and 2, 1862 and 1540, respectively.
Total gain, Lots 1 and 2, 2281.333 and 2193.667 pounds, respectively.

and 41 percent protein soybean oil meal in a ratio supplying approximately equal amounts of protein from each. Another group was fed the same ration as the one just mentioned except that it contained no dried distillers' grain solubles. The results from the use of the three rations are reported in Table 23.

Unlike the results of the previous experiment, there was no benefit from including meat scraps in the ration when it contained dried distillers' grain solubles. On the other hand, when the ration contained meat scraps, fully as good results were obtained without as with dried

Table 23.—A Vitamin B_{12} Supplement and Lysine With Dried Distillers' Grain Solubles When Soybean Oil Meal Is Used as the Protein Concentrate.

Started November 30, 1948 Feeds mixed and self fed	1	2	3	4	5
	Corn, dried distillers' grain solubles*, soybean oil meal, ground alfalfa, minerals, and irradiated yeast				
		Vitamin B_{12} supplement	Vitamin B_{12} supplement and lysine	Meat scraps	Meat scraps without dried distillers' grain solubles
Pigs at start	15	15	15	15	15
Initial weight per pig, lb.	49.0	49.0	48.5	49.5	49.4
Pigs at close	15	15	14	14	15
Final weight per pig, lb.	219.6	212.7	212.6	212.2	217.5
Average daily gain, lb.	**1.35**	**1.56**	**1.43**	**1.35**	**1.41**
Days to gain 160 pounds	119	103	112	119	114
Daily feed per pig, lb.:					
Corn	3.66	4.16	3.86	3.82	4.16
Dried distillers' grain solubles	.25	.29	.27	.25	
Meat scraps (60 percent)				.29	.34
Soybean oil meal	.81	.90	.83	.40	.46
B_{12} supplement		.02	.02		
Lysine			.01		
Ground alfalfa	.25	.29	.27	.25	.26
Minerals	.10	.11	.10	.06	.07
Total	5.07	5.77	5.56	5.07	5.29
Feed per 100 lb. gain, lb.:					
Corn	270.37	267.12	269.12	281.56	294.19
Dried distillers' grain solubles	18.73	18.51	18.68	18.70	
Meat scraps (60 percent)				21.42	24.00
Soybean oil meal	59.81	57.74	58.00	29.14	32.85
B_{12} supplement		1.48	1.49		
Lysine			.75		
Ground alfalfa	18.73	18.51	18.68	18.76	18.73
Minerals	6.92	6.84	6.86	4.59	4.92
Total	**374.56**	**370.20**	**373.58**	**374.11**	**374.69**
Cost of feed per 100 lb. gain	$ 9.84	$ 9.68**	$ 9.75***	$10.11	$ 9.88

* Except Lot 5. **With no charge included for the vitamin B_{12} supplement. ***With no charge included for vitamin B_{12} supplement and the lysine.

Vitamin B_{12} supplement was originally called APF or animal protein factor concentrate.

Total pig days, Lots 1, 2, 3, 4, and 5, 1890, 1575, 1652, 1708, and 1785, respectively. Total gain, Lots 1, 2, 3, 4, and 5, 2559.0, 2454.333, 2370.333, 2314.0, and 2521.0 pounds, respectively.

distillers' grain solubles included in the ration. The pigs used in both this and the preceding experiment were on pasture until they were started on the tests at approximately 10 weeks of age. Further trials will be necessary to determine the advisability of including both dried distillers' grain solubles, or other materials rich in water soluble vitamins, and meat scraps, or an animal protein concentrate, in a corn, soybean oil meal, ground alfafla, minerals ration for dry lot feeding.

APF Concentrate and Distillers' Solubles Used

Two additional groups of pigs were included in the experiment carried on during the winter of 1948-1949. One of these was fed the basal ration plus 0.4 percent of an animal protein factor, APF concentrate, or vitamin B_{12} supplement. The other was fed the basal ration plus

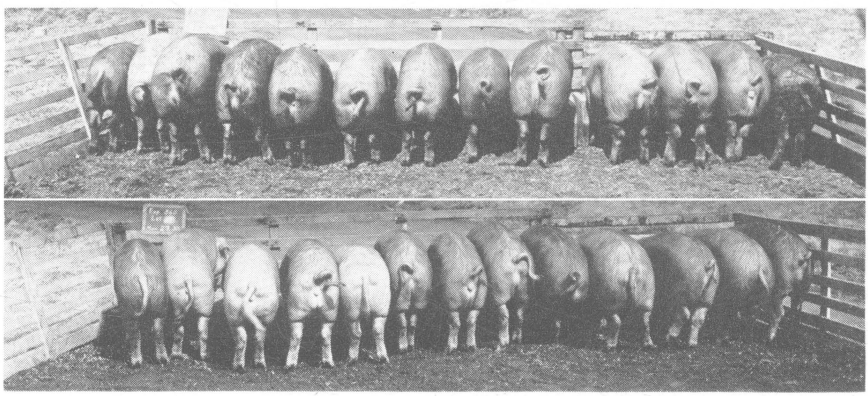


Figure 3.—(top) Lot 6, Corn, meat scraps—60 percent, soybean oil meal, ground alfalfa, irradiated yeast, minerals. Av. daily gain, 1.45 lb. Feed per 100 lb. gain, 373 lb.

(bottom) Lot 5, corn, dried distillers' grain solubles, soybean oil meal, ground alfalfa, irradiated yeast, minerals. Av. daily gain, 1.21 lb. Feed per 100 lb. gain, 383 lb.

0.4 percent of the animal protein factor concentrate and 0.2 percent of synthetic d-l lysine monohydrochloride.

The animal protein factor concentrate used was supplied through the courtesy of Merck and Company, Inc., Rahway, New Jersey. It contained 2 milligrams of vitamin B_{12} activity to the pound. The pigs having the animal protein factor concentrate ate 13.8 percent more feed daily a head, gained 15.6 percent more rapidly and were ready for market 16 days earlier than those on the same ration without it. The difference in the feed required per 100 pounds of gain produced was negligible. It was in favor of the ration containing the concentrate but amounted to only 1.2 percent.

The basal ration to which the animal protein factor concentrate was added contained 5 percent of dried distillers' grain solubles and 5 percent of good quality ground alfalfa. It was a ration which in previous experiments was fully as effective as one containing as much protein from meat scraps or an animal protein concentrate as from soybean oil meal.

APF Concentrate, Lysine, and Distillers' Solubles Tried

The synthetic d-l lysine monohydrochloride used in the experiment was supplied by the courtesy of the Organic Chemical Department, E. I. Du Pont de Nemours Company. Lysine is one of the amino acids or protein fractions that is essential to animals. Plant protein concentrates may or may not contain adequate quantities of these various essential amino acids for the health and optimum performance of animals.

The pigs given both the animal protein factor concentrate and the synthetic d-l lysine monohydrochloride in their ration required as much feed per 100 pounds of gain, in fact 0.9 percent more, and made no faster gains than those given only the animal protein factor concentrate in addition to the basal ration. Although the findings of the one feeding experiment are not regarded as conclusive, they indicate that a ration of the type used containing soybean oil meal as the protein concentrate is not deficient in lysine. Recently published determinations of the amino acid content of various feeds show soybean oil meal to be as high as dried skimmilk and almost as high as meat scraps but not as high as fish meal in lysine.

Animal Protein Feed and APF Concentrate Compared

An experiment in which various materials were tried for feeding with corn, toasted, solvent extracted soybean oil meal, or solvent extracted cottonseed meal, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot was started November 29, 1949. Since no soybean oil meal was fed to Lots 1, 2, and 4, the data for these are not included. The results for the other lots are given in Table 24.

Ground alfalfa and dried distillers' grain solubles, when they were fed, each made up 5 percent of the ration. When used, the meat scraps, which contained 60 percent of protein, were fed at a level that supplied approximately the same amount of protein as the soybean oil meal.

The performance of the pigs in Lot 5, fed the basal ration containing the dried distillers' grain solubles, was not equal to that of the pigs on a similar ration in the experiments reported in Table 21. In the earlier tests and in this one, average daily gains of 1.34 and 1.21, and feed requirements per 100 pounds of gain of 375 and 383 pounds, respectively, were obtained. A pig that gained 0.92 pound

Table 24.—Cobalt With, and Vitamin B_{12} Supplements Without and With Dried Distillers' Grain Solubles, When Soybean Oil Meal Is Used as the Protein Concentrate.

Experiment started November 29, 1949	3	5	6	7	8	9	10	11
	Corn, dried distillers' grain, solubles, soybean oil meal, ground alfalfa, minerals, and irradiated yeast							
The corn was ground and the feeds were mixed and self fed	Cottonseed meal and B_{12} suppl. No. 2		Meat scraps*	Meat scraps	B_{12} suppl. No. 2*	B_{12} suppl. No. 2	B_{12} suppl. No. 3	Cobalt
Pigs at start	13	13	13	13	13	12	13	13
Initial weight per pig, lb.	43.7	45.3	45.1	45.3	45.0	45.7	45.0	45.0
Pigs at close	13	11	13	11	13	12	13	13
Final weight per pig, lb.	208.8	205.7	207.3	210.3	211.1	210.8	211.9	205.7
Average daily gain, lb.	**1.57**	**1.21**	**1.45**	**1.35**	**1.48**	**1.57**	**1.70**	**1.53**
Days to gain 160 pounds	102	133	111	119	108	102	94	105
Daiy feed per pig, lb.:								
Corn	4.18	3.31	4.20	3.72	4.05	4.15	4.27	3.80
Dried distillers' grain solubles	.30	.23		.25			.30	.27
Meat scraps, 60 percent			.36	.29		.29		
Soybean oil meal	.51	.76	.49	.39	1.02	.93	.97	.88
Cottonseed meal	.51							
Vitamin B_{12} supplement	.006				.005	.006	.02	
Ground alfalfa	.30	.23	.27	.25	.274	.29	.30	.27
Minerals	.11	.09	.08	.06	.13	.12	.12	.10
Total	5.91	4.62	5.40	4.96	5.48	5.78	5.98	5.32
Feed per 100 lb. gain, lb.:								
Corn	265.80	273.82	290.20	274.60	273.03	264.09	250.66	248.25
Dried distillers' grain solubles	18.79	19.15		18.34		18.39	17.56	17.37
Meat scraps, 60 percent			24.80	21.42				
Soybean oil meal	32.38	63.20	33.87	29.24			57.02	57.44
Cottonseed meal	32.38							
Vitamin B_{12} supplement	.37				.37	.37	1.40	
Ground alfalfa	18.79	19.15	18.64	18.34	18.47	18.39	17.56	17.37
Minerals	7.31	7.66	5.24	4.79	8.64	7.35	7.02	6.95
Total	375.82	382.98	372.75	366.73	369.44	367.83	351.23	347.38
Cost of feed per 100 lb. gain	$10.49	$10.24	$ 9.95	$10.01	$10.12	$10.30	$ 9.95	$ 9.31

* With dried distillers' grain solubles omitted from the ration.

Total pig days, Lots 3, 5, 6, 7, 8, 9, 10, and 11 = 1365, 1533, 1456, 1393, 1456, 1260, 1274, and 1365, respectively. Total gains, Lots 3, 5, 6, 7, 8, 9, 10, and 11 = 2146.0, 1850.5, 2109.33, 1885.33, 2160.0, 1981.33, 2169.5, and 2088.67, respectively.

Toasted solvent extracted 44 percent protein soybean oil meal, 60 percent protein meat scraps, and 41 percent protein solvent extracted cottonseed meal were fed.

To prevent any harmful effect from the free gossypol it contained, a solution of 0.1 lb. of ferrous sulfate in one quart of water was added to each 10 pounds of the cottonseed meal before it was mixed with the other feeds.

All rations contained 0.01 percent of irradiated yeast as a source of vitamin D. In the table it is included with the corn, with a small quantity of which it was pre-mixed.

Each ration contained approximately 16.5 pounds of protein until the pigs in the lot averaged approximately 120 pounds in weight, and 14.5 percent of protein thereafter.

Cobaltous chloride ($CoCl_2 . 6H_2O$) was fed at the rate of 0.15 percent of the mineral mixture. The mineral mixture for Lot 11 made up 2 percent of their ration.

Vitamin B_{12} supplement No. 2, containing 12.5 milligrams of B_{12} activity to the pound, and vitamin B_{12} supplement No. 3, containing approximately 3 to 4 milligrams of B_{12} activity to the pound, were fed at the rates of 0.1 and 0.4 percent of the ration, respectively.

daily for the first 14 days gained only 0.27 pound daily for the next 42 days, and so was removed. In the data given in Table 24 it was figured as out on the 14th day. No feed was deducted for that consumed by it during the 42 days. A second pig, which gained 1.25 pounds daily and was the best doing one in the lot, for the first 56 days, died on the 70th day. It was diagnosed as having died from a hemorrhage apparently resulting from a stomach ulcer. If it is assumed that from the 14th to the 56th day and from the 56th to the 64th day, respectively, the two, as named, consumed half as much feed as was taken daily a head by the group, the feed required per 100 pounds of gain produced would be 378 instead of 383 pounds.

A mild infection for a time may have retarded the gains of the other pigs in the lot. Regardless of whether the gains made by the one pig for the 14 days or by the other for the 56 days were included or omitted, the average daily gain for the lot was not changed. The pigs remaining in Lot 5 at the close of the experiment gained 1.21 pounds daily a head.

The pigs in Lot 6, fed meat scraps but no dried distillers' grain solubles, ate more feed, gained more rapidly, were ready for market 22 days earlier and made more gain per unit of feed than the pigs in Lot 5 fed dried distillers' grain solubles but no meat scraps. They made more rapid gains but their feed requirement per unit of gain was about the same as that of the pigs having dried distillers' grain solubles but no meat scraps in the experiments reported in Table 21.

The pigs of Lot 7 having a combination of meat scraps and dried distillers' grain solubles in their ration gained 4.0 percent more slowly and were ready for market 8 days later but required 1.6 percent less feed per unit of gain than the pigs of Lot 6 having meat scraps but no dried distillers' grain solubles. This difference in the rapidity of the gains was based on the gains made by the pigs remaining in Lot 7 at the close of the test, which was 1.39 pounds daily a head.

Lot 8 was fed a ration containing 0.1 percent of an APF concentrate but no dried distillers' grain solubles. Lot 9 was fed a ration containing an equal amount of the same APF concentrate and 5 percent of dried distillers' grain solubles. The APF concentrate which is designated as Number 2 was supplied through the courtesy of Merck and Company, Inc., was derived from the manufacture of streptomycin, which was produced with the microorganism Streptomyces griseus by a fermentation process, contained fuller's earth as an adsorbate and had a vitamin B_{12} activity of 12.5 milligrams to the pound.

Including the APF concentrate Number 2 but no dried distillers' grain solubles in the ration containing soybean oil meal as the high-

protein feed was as effective as using meat scraps in combination with the soybean oil meal.

Pigs having both the APF concentrate Number 2 and dried distillers' grain solubles in their ration made virtually no more gain per unit of feed consumed but took more feed, gained 6.0 percent more rapidly and were ready for market 6 days earlier than those having only the APF concentrate included in their ration.

Experiments with poultry and also with pigs, such as those reported in Tables 15 and 20 and elsewhere in this publication, showed that liver or glandular meal, fish meal, condensed fish solubles, milk, milk products, tankage, and meat scraps, though they contain varying amounts, are natural sources of a health, reproductive and growth promoting factor, or factors, that is not present in appreciable amounts in cereals or in high-protein feeds of plant origin. This factor was given various names. It is a vitamin or vitamin complex and not a protein, but, since it is closely associated with animal proteins, it was first commonly referred to as the animal protein factor, or APF, but is now known as vitamin B_{12}. Yeast and dried distillers' grain solubles are rich in other B vitamins, but are relatively poor sources of the vitamin B_{12} (1, 20).

When vitamin B_{12} was first isolated, it and the animal protein factor were thought to be identical. Its isolation enabled various studies

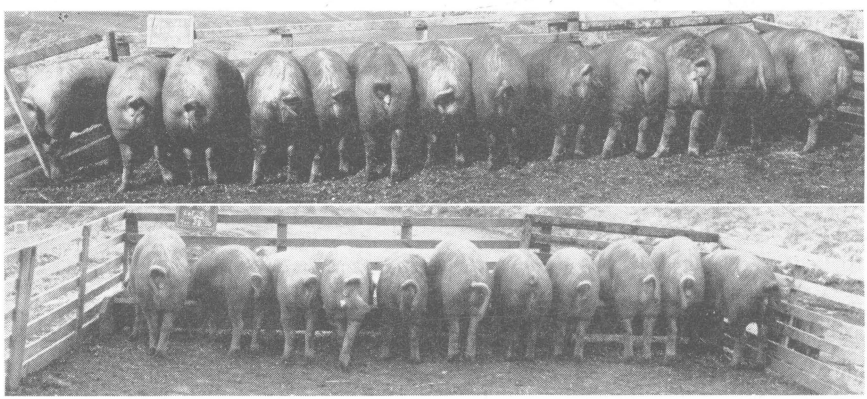


Figure 4.—(top) Lot 3, corn, dried distillers' grain solubles, soybean oil meal, iron treated solvent extracted cottonseed meal, ground alfalfa, irradiated yeast, minerals. Av. daily gain, 1:57 lb. Feed per 100 lb. gain, 376 lb.
(bottom) Lot 11, corn, dried distillers' grain solubles, soybean oil meal, ground alfalfa, irradiated yeast, minerals containing cobaltous chloride. Av. daily gain, 1.53 lb. Feed per 100 lb. gain, 347 lb.

concerning it to be made. It was found to prevent pernicious anemia in humans (26, 27) and to be essential for the growth of chickens and pigs (2, 9, 11, 15). It was demonstrated to contain cobalt and phosphorus (16).

Pure vitamin B_{12} is too costly for use in practical rations for swine. Fortunately vitamin B_{12} supplements have become available and can be secured at prices which are not prohibitive, for use in rations for swine. Although they were used experimentally at an earlier date, these supplements first became available to the feed trade in the summer of 1949.

The animal protein factor, or factors, is needed in rations for poultry and pigs (10, 13, 17). It is not required in rations for cattle, sheep, and goats. Microorganisms in the rumen of polygastric animals synthesize it and other vitamins of the B complex in the fermentative processes of digestion. Hence, except possibly in the young, before synthesis has started, or in animals on rations unfavorable to synthesis, ruminants are not likely to suffer from a deficiency of B vitamins.

An interesting finding was that cow manure was an effective source of the animal protein factor (7). This explains why runty pigs often improve when placed with cattle and suggests that pigs may sometimes be provided with the animal protein factor by allowing them to follow cattle.

Ruben, Bird, and Rothchild (21) found that the animal protein factor was present in hen droppings but that it was not available to the hen itself. McGinnis, Stevens, and Groves (11) found that the factor was synthesized in hen feces by bacterial activity after the feces were voided and that there was a live microorganism in hen feces that could produce the factor. Microorganisms have been isolated from the soil which in suitable media also produce vitamin B_{12}.

Some synthesis of B vitamins probably including B_{12} occurs in the large intestine of swine, particularly in older animals and under favorable conditions but apparently the synthesis does not occur where much absorption can take place or else often the vitamins are not produced in sufficient quantities to meet the requirements for optimum performance.

Vitamin B_{12} supplements are obtained as fermentation products from the microorganisms that are used in the production of antibiotics such as streptomycin, aureomycin, and terramycin. Usually materials which serve as conditioning agents are added to the dried fermentation products.

Lot 10 received a ration similar to that fed Lot 9 except that it contained a different APF concentrate that was designated as Number 3. This was a dry concentrate containing some soybean oil meal to make it free-flowing. It was supplied through the courtesy of the Lederle Laboratories Division of the American Cyanamid Company. It was derived from the production of the antibiotic aureomycin through a fermentation process by the microorganism S. aureofaciens. It was stated to have the equivalent of 3 to 4 milligrams of B_{12} activity to the pound of concentrate. The concentrate was fed at the rate of 0.4 percent of the total ration.

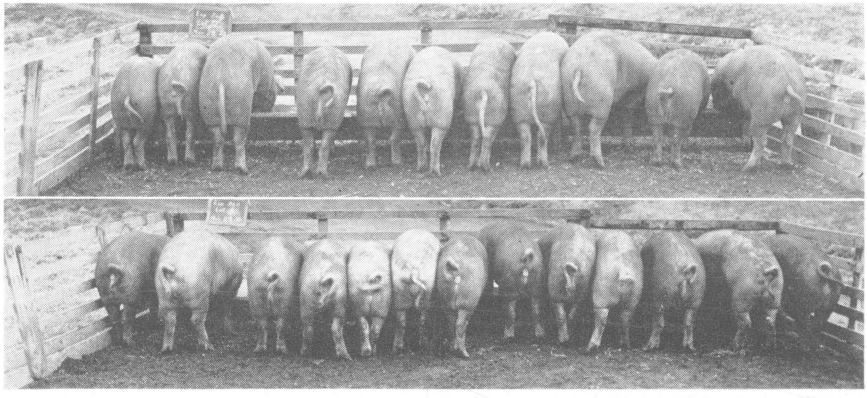


Figure 5.—(top) Lot 7, corn, dried distillers' grain solubles, meat scraps—60 percent, soybean oil meal, ground alfalfa, irradiated yeast, minerals. Av. daily gain, 1.39 lb. Feed per 100 lb. gain, 367 lb.

(bottom) Lot 8, corn soybean oil meal, vitamin B_{12} supplement, ground alfalfa, irradiated yeast, minerals. Av. daily gain, 1.48 lb. Feed fed per 100 lb. gain, 369 lb.

The pigs receiving the APF concentrate Number 3 ate 3.5 percent more feed daily a head, gained more rapidly, were ready for market 8 days earlier and required 4.5 percent less feed per unit of gain than the pigs in Lot 9 having the APF concentrate Number 2, but an otherwise similar ration.

A pig that failed to gain was removed from Lot 9 after 14 days and was figured as out from the start, but, since the amount was not known, no feed was deducted for what was consumed by it until it was removed. Assuming that it ate as much feed as the others, which is extremely improbable, and deducting this amount would result in Lot 9 requiring 365.5 pounds of feed, or 4 percent more than Lot 10, for each 100 pounds of gain produced.

Apparently the APF concentrate Number 3 possessed a growth or health promoting value not possessed by the APF concentrate Number 2. Such a value could be due to one or more additional factors or to an antibiotic effect from aureomycin residues. Except for the pig removed from Lot 9 on the 14th day, the health of all the pigs in each group appeared to be excellent. The results were in accord with the findings of Stokstad, Jukes, Pierce, Page, and Franklin (23) who reported that chicks on a corn, soybean oil meal diet which contained the other known B vitamins appeared to require some factor in addition to vitamin B_{12} for maximum growth.

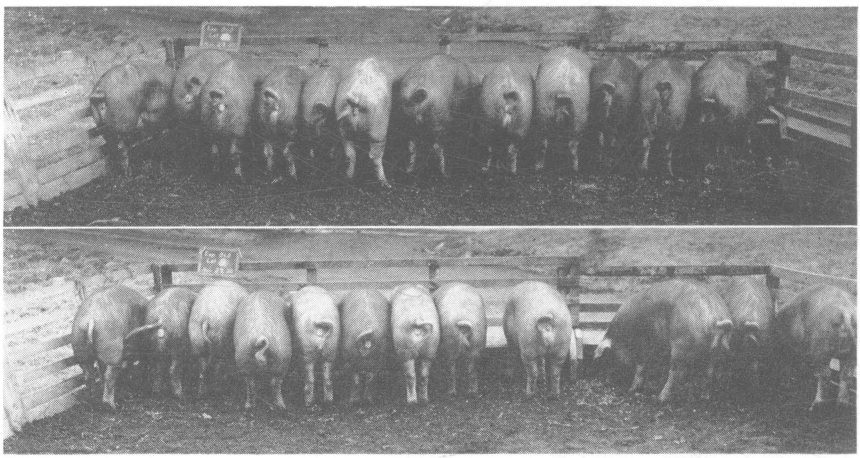


Figure 6.—(top) Lot 9, corn, dried distillers' grain solubles, soybean oil meal, vitamin B_{12} supplement, ground alfalfa, irradiated yeast, minerals. Av. daily gain, 1.57 lb. Feed per 100 lb. gain, 368 lb.

(bottom) Lot 10, corn, dried distillers' grain solubles ,soybean oil meal, vitamin B_{12} and antibiotic supplement, ground alfalfa, irradiated yeast, minerals. Av. daily gain, 1.70 lb. Feed fed per 100 lb. gain, 351 lb.

The performance of the pigs in Lot 10 was superior to that of the pigs in Lots 6 and 7, which received meat scraps in combination with soybean oil meal. Further work is needed to verify this but if high-protein feeds of animal origin supply the same growth and health promoting factors as the APF concentrate Number 3 apparently the amounts supplied by them are not always adequate for the optimum performance of the animals, particularly when the animal protein feeds are used in limited quantities or to supply only a part of the supplemental protein.

Lot 3 was fed a ration in which solvent extracted cottonseed meal, that was treated with a solution of ferrous sulfate to prevent any deleterious effect from the free-gossypol it contained, was substituted for half of the toasted solvent extracted soybean oil meal. A tenth of a percent of the APF concentrate Number 2 was included in the ration. It produced as rapid gains but hardly as much gain per unit of feed as the ration fed Lot 9 in which the high-protein feed consisted of soybean oil meal alone.

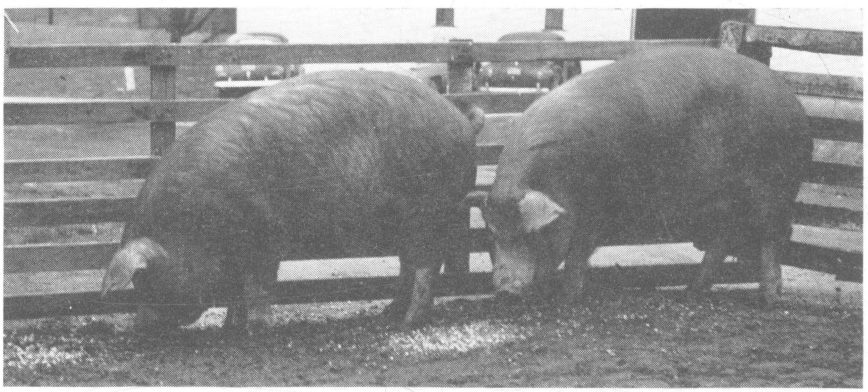


Figure 7.—Ration of corn, dried distillers' grain solubles, soybean oil meal, ground alfalfa, irradiated yeast, minerals. (left) Without B_{12} and antibiotic supplement, av. daily gain, 1.41 lb. and (right) with B_{12} and antibiotic supplement, av. daily gain, 1.72 lb.

Figure 8.—(left) Corn, dried distillers' grain solubles, soybean oil meal, meat scraps—60 percent, ground alfalfa, irradiated yeast, and minerals. Av. daily gain, 1.38 lb.

(right) Corn, dried distillers' grain solubles, soybean oil meal, vitamin B_{12} and antibiotic supplement, ground alfalfa, irradiated yeast, and minerals. Av. daily gain, 1.72 lb.

Minute Quantity of Cobaltous Chloride in Mineral Mixture

Lot 11 was fed the same ration as Lot 5 except that 0.15 of one percent of cobaltous chloride ($CoCl_2.6H_2O$) was included in their mineral mixture. The mineral mixture was fed at the rate of 2 pounds in each 100 pounds of total feed. Cobalt is one of the constituents of the rather complex molecule of vitamin B_{12}. The pigs having cobalt in their minerals gained 26 percent more rapidly and required 9.3 percent less feed per unit of gain than those on the same ration without it.

As previously mentioned, the pigs in Lot 5 on the basal ration in this experiment failed to do as well as pigs on a similar ration in earlier experiments. Using the results of the earlier experiments reported in Table 21 as a basis of comparison, the difference in the rapidity of the gains and in the amount of feed required per unit of gain was 14.2 and 7.4 percent, respectively, in favor of the cobalt fed group.

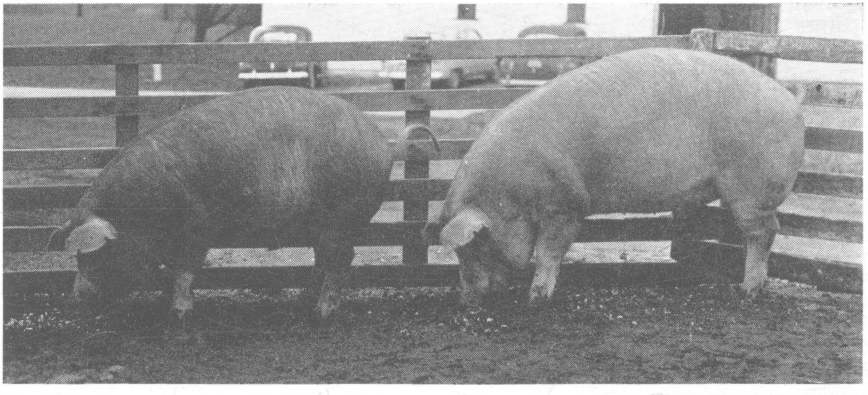


Figure 9.—Corn, dried distillers' grain solubles, soybean oil meal, ground alfalfa, irradiated yeast, iodized salt, limestone, special steamed bone meal, and ferrous sulfate with (left) no cobaltous chloride, av. daily gain, 1.34 lb. and (right) with cobaltous chloride, av. daily gain, 1.62 lb.

The pigs having cobalt were not ready for market until 11 days later but required no more feed per unit of gain than those having the APF concentrate Number 3. They made more rapid gains and greater gains per unit of feed consumed than those having a part of the soybean oil meal replaced with meat scraps. Further comparisons of rations containing soybean oil meal or a mixture of soybean oil meal and meat scraps as the protein concentrate when they are fed with and without the addition of a minute quantity of cobalt will be of interest and are needed before conclusions concerning the worth of cobalt in the ration are warranted.

FISH MEAL AND MEAT SCRAPS COMPARED FOR FEEDING WITH SOYBEAN OIL MEAL

Six experiments were conducted in which meat scraps and fish meal were compared for feeding with yellow corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot. Each was fed at the same rate as the soybean oil meal. Table 25 summarizes the results of the six experiments.

There was practically no difference in the average performance of the two groups. Meat scraps and fish meal were equally effective for feeding in combination with soybean oil meal to pigs in dry lot. Since

Table 25.—Comparison of Meat Scraps and Fish Meal for Feeding with Soybean Oil Meal to Pigs in Dry Lot.

Experiments conducted: 1938 to 1946	1 Corn **Meat scraps** Soybean oil meal Ground alfalfa Minerals	2 Corn **Fish meal** Soybean oil meal Ground alfalfa Minerals
Number of comparisons	6	6
Pigs at start	82	84
Initial weight per pig, lb.	53.9	53.5
Pigs at close	75	81
Final weight per pig, lb.	214.8	213.3
Average daily gain, lb.	**1.34**	**1.36**
Days to gain 160 pounds	120	118
Daily feed per pig, lb.:		
Corn	4.24	4.29
Meat Scraps	.39	
Fish meal		.39
Soybean oil meal	.39	.39
Ground alfalfa	.21	.22
Minerals	.08	.08
Total	5.31	5.37
Feed per 100 lb. gain, lb.:		
Corn	316.10	315.75
Meat Scraps	29.19	
Fish meal		28.77
Soybean oil meal	29.19	28.77
Ground alfalfa	15.85	15.80
Minerals	5.85	5.90
Total	**396.18**	**394.99**
Cost of feed per 100 lb. gain	$10.53	$10.54

Total pig days, Lots 1 and 2, 9282 and 9632, respectively.

Total gain, Lots 1 and 2, 12,451.5 and 13,087.833 pounds, respectively.

fish meal contains more lysine than meat scraps, these results are a further indication that soybean oil meal is not deficient in lysine.

SOYBEAN OIL MEAL AND LINSEED MEAL COMPARED FOR FEEDING WITH MEAT SCRAPS

Six experiments were also conducted in which linseed meal and good quality soybean oil meal were compared for feeding with corn, meat scraps, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot. Both the linseed meal and the soybean oil meal were fed at the same rate as the meat scraps. Table 26 summarizes the six experiments.

Table 26.—Comparison of Linseed Meal and Soybean Oil Meal for Feeding with Meat Scraps to Pigs in Dry Lot.

Experiments conducted: 1938 to 1946	1 Corn **Linseed meal** Meat scraps Ground alfalfa Minerals	2 Corn **Soybean oil meal** Meat scraps Ground alfalfa Minerals
Number of comparisons	6	6
Pigs at start	85	83
Initial weight per pig, lb.	52.6	53.5
Pigs at close	81	78
Final weight per pig, lb.	207.2	211.0
Average daily gain, lb.	**1.40**	**1.31**
Days to gain 160 pounds	115	123
Daily feed per pig, lb.:		
Corn	4.32	4.14
Linseed meal	.44	
Soybean oil meal		.38
Meat scraps	.44	.38
Ground alfalfa	.22	.20
Minerals	.08	.07
Total	5.50	5.17
Feed per 100 lb. gain, lb.:		
Corn	309.33	316.04
Linseed meal	31.72	
Soybean oil meal		28.83
Meat scraps	31.72	28.83
Ground alfalfa	15.60	15.67
Minerals	5.40	5.72
Total	**393.77**	**395.09**
Cost of feed per 100 lb. gain	$10.45	$10.49

Total pig days, Lots 1 and 2, 9114 and 9527, respectively.
Total gain, Lots 1 and 2, 12,736.167 and 12,467.5 pounds, respectively.

The pigs having soybean oil meal ate 6.0 percent less feed daily a head, gained 6.4 percent less rapidly and were not ready for market until 8 days later, on the average, than were those fed linseed meal. Possibly the ration containing soybean oil meal was deficient in the so-called animal protein factor. There was a difference of only 0.34 percent in the average amounts of feed required per unit of gain by the pigs having linseed meal and by those having soybean oil meal in combination with meat scraps.

SOYBEAN OIL MEAL FOR PIGS ON PASTURE

Except for those in which raw and cooked soybeans were compared with soybean oil meal for pigs on pasture, the experiments reported thus far have dealt with feeding soybean oil meal to pigs in dry lot. Since a large share of the pigs produced annually in the United States are fed on pasture, data on the worth of soybean oil meal as a protein concentrate for pigs on pasture are also of interest.

Fed as Only Protein Concentrate

Table 27 summarizes six experiments in which 60 percent protein meat scraps or dry rendered tankage and soybean oil meal were compared for feeding with corn and minerals to pigs on pasture. The pastures used were three of Dwarf Essex rape and three of a mixture of alfalfa and medium red clover from which an early cutting had first been removed.

In each experiment the shelled corn was ground. It and the high protein feed and the minerals were mixed in proportions giving approximately the same amounts of total protein and minerals in the rations regardless of the particular protein concentrate used. In two of the experiments the pigs were full fed or given all the feed they would take readily twice daily. In the others they were self fed. Good quality expeller soybean oil meal was used in five and toasted solvent extracted soybean oil meal in one of the experiments. The toasted solvent extracted soybean oil meal made up 21.54 percent of the total amount fed in the six experiments. The expeller meal was sold to contain 41, and the extracted meal, 44 percent of protein. This would give the soybean oil meal used an average protein content of approximately 41.6 percent.

When soybean oil meal is properly made it is very palatable to pigs. The pigs fed the rations containing soybean oil meal ate 8.9 percent more feed daily a head, gained 6.4 percent more rapidly, and were ready for market 7 days earlier, on the average, but required 2.4 percent more feed per unit of gain than those having the rations containing 60 percent protein meat scraps or dry rendered tankage.

Table 27.—Meat Scraps and Soybean Oil Meal as Protein Concentrates for Pigs on Pasture.

Experiments conducted: 1919 to 1943	1 Corn Meat scraps Minerals	2 Corn Soybean oil meal* Minerals
Number of experiments	6	6
Pigs at start	94	95
Initial weight per pig, lb.	55.1	54.9
Pigs at close	89	93
Final weight per pig, lb.	209.6	212.4
Average daily gain, lb.	**1.34**	**1.43**
Days to gain 160 pounds	120	113
Daily feed per pig, lb.:		
Corn	4.47	4.62
Meat scraps	.38	
Soybean oil meal		.62
Minerals	.07	.12
Total	4.92	5.36
Feed per 100 lb. gain, lb.:		
Corn	333.23	323.55
Meat scraps	28.07	
Soybean oil meal		43.48
Minerals	5.41	8.31
Total	366.70	375.34
Cost of feed per 100 lb. gain	$ 9.56	$ 9.43
Cost of feed and pasture per 100 pounds of gain	$11.05	$10.83

* Toasted solvent extracted soybean oil meal was used in one and good quality expeller soybean oil meal in the other five experiments. The toasted solvent extracted soybean oil meal made up 21.54 percent of the total amount fed in the six experiments.

Total pig days, Lots 1 and 2, 10,416 and 10,332, respectively. Total gain, Lots 1 and 2, 13,982.833 and 14,757.833 pounds, respectively.

As determined from the prices used for them and the amounts of the other feeds replaced per unit of gain by it, the soybean oil meal showed a value 71.2 percent that of an equal weight of the 60 percent protein meat scraps or dry rendered tankage. Thus, for feeding on good pasture, and when it was fortified with a sufficient amount of minerals to make the total mineral content of the rations the same, soybean oil meal gave fully as good results and proved to be worth as much per pound of protein contained as 60 percent protein meat scraps or dry rendered tankage.

Possibly the significance of the pasture being good in enabling such favorable results to be obtained from the use of soybean oil meal as a high protein feed should be stressed. Good pasture is succulent,

and contains an ample amount of tender, palatable, new growth. Such pasture is considerably higher in protein than are the grains, contains proteins of good quality, is rich in minerals, particularly calcium, and is an excellent source of vitamins, especially the water soluble vitamins or those of the B complex. Other than sodium chloride or common salt, which is easily supplied, calcium is the mineral element most likely to be needed in rations commonly fed to pigs. In the experiments previously reported, materials rich in vitamins of the B complex were shown to be beneficial with rations of yellow corn, ground alfalfa, minerals, irradiated yeast, and soybean oil meal. Good pasture tends to

Table 28.—Meat Scraps, Soybean Oil Meal and Mixture of Soybean Oil Meal and Cottonseed Meal as Protein Concentrates for Pigs on Pasture.

Experiments conducted: 1940, 1941 and 1942 Feeds mixed and self fed	1 Corn **Meat scraps** Minerals	2 Corn **Soybean oil meal** Minerals	3 Corn **Soybean oil meal Cottonseed meal** Minerals
Number of experiments	3	3	3
Pigs at start	59	60	60
Initial weight per pig, lb.	53.5	53.1	53.6
Pigs at close	55	59	55
Final weight per pig, lb.	207.2	207.5	214.3
Average daily gain	**1.33**	**1.40**	**1.43**
Days to gain 160 pounds	121	115	112
Daily feed per pig, lb.:			
Corn	4.35	4.49	4.45
Meat scraps	.41		
Soybean oil meal		.66	.38
Cottonseed meal			.30
Minerals	.07	.13	.13
Total	4.83	5.28	5.26
Feed per 100 lb. gain, lb.:			
Corn	327.05	321.15	310.93
Meat scraps	30.28		
Soybean oil meal		47.25	26.46
Cottonseed meal			21.27
Minerals	5.45	9.22	8.96
Total	**362.78**	**377.62**	**367.62**
Cost of feed per 100 lb. gain	$ 9.53	$ 9.56	$ 9.30
Cost of feed and pasture per 100 pounds of gain	$11.03	$10.99	$10.70

Total pig days, Lots 1, 2, and 3, 6461, 6559, and 6349, respectively. Total gain, Lots 1, 2, and 3, 8596.5, 9179.5, and 9091.667 pounds, respectively.

correct the deficiencies that may exist in the non-carbonaceous portion of the ration. On the other hand, the nutritional needs of pigs on poor pasture would not be greatly different from those of pigs in dry lot.

Fed With Cottonseed Meal

In three of the six experiments in which soybean oil meal and 60 percent protein meat scraps were compared as high-protein feeds for pigs on pasture, a third group was fed a mixture of soybean oil meal and cottonseed meal. The corn was ground and the rations were mixed so the total protein and total minerals were approximately the same regardless of the high-protein feed used. Self feeding was practiced. The amount of protein in the ration was reduced from approximately 14 to 12 percent when the pigs averaged 120 pounds in weight. Toasted solvent extracted soybean oil meal was fed in one and expeller soybean oil meal was fed in two of the experiments. The cottonseed meal fed in one of the tests was made by the hydraulic and in two by the expeller process. Although under the conditions and in the amounts fed, it was not expected to prove deleterious, in one of the experiments, in order to overcome any possible toxic effect from the free-gossypol it might contain, the cottonseed meal was treated with a solution of ferrous sulfate. The soybean oil meal and the cottonseed meal were fed in 2:1 ratio in one and in a 1:1 ratio in two of the experiments. Table 28 shows the results secured from the three supplements.

There was little difference in the average performance of the pigs fed soybean oil meal and of those fed a mixture of soybean oil meal and cottonseed meal. The pigs fed the mixture took approximately the same amount of feed daily a head, were ready for market 3 days earlier, on the average, and required 2.6 percent less feed per unit of gain than those fed only soybean oil meal as a protein concentrate. Those fed the mixture ate more feed daily a head, gained 7.5 percent more rapidly, and required 1.3 percent more feed per unit of gain than those fed 60 percent protein meat scraps.

Fed With Linseed and Cottonseed Meal

A mixture of soybean oil meal, cottonseed meal and linseed meal in a 4:1:1 ratio was compared with soybean oil meal and with 60 percent protein meat scraps for feeding with corn and minerals to pigs on pasture in two experiments. The shelled corn was ground and the feeds were mixed so that each ration contained approximately the same percentage of total protein and total minerals. Self feeding was practiced. In one of the experiments the pasture used was Dwarf Essex rape. In the other, it was a mixture of alfalfa and medium red clover from which an early cutting had been removed. Table 29 summarizes the results of the two experiments.

The differences in the feed consumed daily a head, in the rapidity of the gains and in the feed required per unit of gain by the pigs fed soybean oil meal and by those fed the mixture were so small as to be negligible. All three groups required approximately the same amount of feed per 100 pounds of gain produced.

The pigs fed the soybean oil meal and those fed the mixture ate a little more feed daily a head and gained a little more rapidly so that they were ready for market 4 days and 6 days earlier, respectively, than those fed the 60 percent protein meat scraps.

Table 29.—Meat Scraps, Soybean Oil Meal and Mixture of Three High-Protein Feeds from Plant Sources as Protein Concentrates for Pigs on Pasture.

Experiments conducted: 1942 and 1943 Feeds mixed and self fed	1 Corn **Meat scraps** Minerals	2 Corn **Soybean oil meal** Minerals	3 Corn **Soybean oil meal** **Cottonseed meal** **Linseed meal** Minerals
Number of experiments	2	2	2
Pigs at start	40	40	40
Initial weight per pig, lb.	61.5	61.2	62.0
Pigs at close	39	39	39
Final weight per pig, lb.	217.3	218.8	220.3
Average daily gain, lb.	**1.39**	**1.44**	**1.46**
Days to gain 160 pounds	116	112	110
Daily feed per pig, lb.:			
Corn	4.65	4.57	4.59
Meat scraps	.40		
Soybean oil meal		.66	.47
Cottonseed meal			.12
Linseed meal			.12
Minerals	.08	.13	.13
Total	5.13	5.36	5.43
Feed per 100 lb. gain, lb.:			
Corn	335.10	317.67	313.94
Meat scraps	29.20		
Soybean oil meal		45.87	32.10
Cottonseed meal			8.02
Linseed meal			8.02
Minerals	6.02	9.22	9.17
Total	**370.32**	**372.76**	**371.25**
Cost of feed per 100 lb. gain	$ 9.68	$ 9.39	$ 9.35
Cost of feed and pasture per 100 pounds gain	$11.13	$10.78	$10.72

Total pig days, Lots 1, 2, and 3, 4445, 4298, and 4263, respectively. Total gain, Lots 1, 2, and 3, 6161.833, 6183.833, and 6232.5 pounds, respectively.

Fed With Both Animal and Plant Protein Concentrates

In four pasture trials in which both were fed with corn and minerals, pigs given a supplement containing one to three high-protein feeds from animal sources and two or three high-protein feeds from plant sources were ready for market only one day earlier. They required only 0.8 percent less feed per unit of gain, on the average, than pigs given 60 percent protein meat scraps or tankage as a protein concentrate.

In pasture experiments in which they were fed with corn and minerals good quality soybean oil meal was practically as effective as mixtures of it and other plant protein concentrates. Good quality soybean oil meal gave equally as good results as meat scraps or tankage. Meat scraps or tankage or a single high-protein feed from an animal source was practically as effective as a variety or mixture of high-protein feeds from both animal and plant sources. Thus the experiments indicated that, for pigs on good pasture, the protein concentrate to use for the most economical results, as long as it was a suitable one, was the one that supplied protein at the lowest cost per pound.

SUMMARY AND CONCLUSIONS

Experiments with soybean oil meal as a high-protein feed for pigs are reported. The report is a sequel to Bulletin 452, Soybeans and Soybean Oil Meal for Pigs.

The investigations reported cover 42 dry lot and 12 pasture experiments that were conducted in the period from 1916 to 1950. They contained 291 groups and a total of 3,269 pigs.

The objectives were to secure information on the relative values of soybean oil meal alone or in mixtures and other high-protein feeds and to find ways of increasing the effectiveness of soybean oil meal as a supplement to corn for pigs.

Usually the pigs in the various groups were carried to a given average approximate final weight of from 200 to 220 pounds rather than for a given length of time. In most instances, ground shelled corn was fed and the rations were mixed to contain equivalent amounts of total protein regardless of what high-protein feed was used. Sufficient minerals were added to make the total mineral content of the rations approximately the same. As each group reached an approximate average weight of 120 pounds, the protein content of the ration was reduced.

The pigs in the dry lot experiments were kept indoors. From 1926 on, green, leafy, third-cutting, sun-cured, ground alfalfa commonly constituted from 4 to 5 percent of the dry lot rations. Starting in 1942, 0.01 percent of irradiated yeast was used in the dry lot rations as a source of vitamin D.

Data on the worth of soybean oil meals made by the hydraulic, the expeller, and the solvent extraction process and by different techniques or procedures of manufacture were obtained. Different materials were tried with or were added to a corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast ration in efforts to improve it for dry lot feeding.

Among the materials added were (1) oats or another grain, (2) cottonseed meal and a linseed and cottonseed meal mixture, or other high-protein feeds of plant origin, (3) a larger amount of ground alfalfa during the growing period, (4) legume silage, (5) methionine, (6) lysine, (7) high-protein feeds of animal origin, (8) dried brewers' yeast, (9) yeast grown in the wet feed, (10) condensed fish solubles, (11) dried distillers' grain solubles, (12) the trace mineral cobalt, (13) a vitamin B_{12} supplement, and (14) a concentrate containing both vitamin B_{12} and residues of the antibiotic aureomycin.

In the pasture trials, soybean oil meal was compared with mixtures and with other single protein concentrates for feeding with corn and minerals.

In the pasture experiments reported, the corn was ground and the feeds were mixed, so that regardless of the protein concentrate used, the different rations contained approximately the same percentage of total protein and also the same percentage of total minerals. Usually ample green feed was available. Under these conditions, the following conclusions were drawn.

Raw soybeans were unsatisfactory as a high-protein feed for pigs.

Cooked soybeans were a satisfactory high-protein feed for pigs so far as production was concerned but, because of their richness in softening oil and the consequent danger of them producing soft pork if fed with corn in more than limited amounts, were not suitable for pigs intended for slaughter.

Since a large share of the oil is removed in its manufacture, soybean oil meal was free from the objection of producing soft pork.

Regardless of the method of manufacture, thorough cooking or toasting of soybean oil meal, during, preceding or following, the process of removing the oil was necessary before good results could be secured from its use as a feed for pigs.

A ration of corn, soybean oil meal, five percent high quality alfalfa, irradiated yeast, and a simple mineral mixture of salt, limestone, bone meal, and ferrous sulphate was deficient in one or more respects for pigs in dry lot.

Oats, cottonseed meal, or a mixture of linseed and cottonseed meal in the ration were slightly beneficial but did not overcome the deficiency.

Third cutting, ground alfalfa, of average or below average rather than of high quality, at a 15 percent level during the growing period and a five percent level thereafter gave no better results with a soybean oil meal ration than the same alfalfa at a five percent level for the entire time.

Neither 0.2 percent of synthetic methionine nor 0.2 percent of synthetic lysine improved the ration.

The ration was improved by the substitution of fish meal, tankage, or meat scraps for a part of the soybean oil meal.

Including dried brewers' yeast, condensed fish solubles, or dried distillers' grain solubles, or adding water and growing yeast in the wet feed for 24 hours increased the effectiveness of the soybean oil meal ration. These supply water soluble or B-complex vitamins. Yeast and dried distillers' grain solubles, however, are low in vitamin B_{12}.

The use of a vitamin B_{12} supplement with the soybean oil meal ration definitely improved the appetite, the rate of growth, and the health of the pigs.

A combination of a vitamin B_{12} supplement and dried distillers' grain solubles was superior to either alone or to meat scraps for feeding with corn, soybean oil meal, ground alfalfa, minerals, and irradiated yeast to pigs in dry lot.

When each was fed with a soybean oil meal ration containing five percent of dried distillers' grain solubles, a vitamin B_{12} supplement produced faster gains but no greater gains per unit of feed than meat scraps.

A further increase in the effectiveness of a soybean oil meal ration containing dried distillers' grain solubles was brought about by the use of a vitamin B_{12} and antibiotic supplement.

Both the rapidity and the efficiency of the gains of pigs having the vitamin B_{12} and antibiotic supplement surpassed those of pigs having meat scraps. Each was fed in a ration that contained five percent of dried distillers' grain solubles. The meat scraps and soybean oil meal were fed at rates which supplied equivalent amounts of protein.

In a single trial not warranting definite conclusions, cobalt was beneficial in the minerals when a ration of corn, dried distillers' grain solubles, soybean oil meal, alfalfa, minerals, and irradiated yeast was fed. The pigs having cobalt made as much gain per unit of feed but not as rapid gains as pigs on a similar ration without cobalt but with a vitamin B_{12} and antibiotic supplement.

When salt, limestone, bone meal, and ferrous sulphate were included in the ration, good quality soybean oil meal was as effective a supplement to corn for pigs on good pasture as meat scraps, tankage, or mixtures of high-protein feeds.

BIBLIOGRAPHY

1) Cary, C. A., A. M. Hartman; 1943-1947. Unidentified Nutrients; U. S. D. A. Yearbook of Agriculture, 1943-1947, pp. 779-786.
2) Colby, R. W., M. E. Ensminger, 1950. Effect of Vitamin B_{12} on the Growing Pig. Jour. An. Sci., Vol. 9, No. 1, pp. 90-93.
3) Ellis, N. R., J. H. Zeller, J. N. King, 1943. The Value of Ground Legume Hays in Rations of Fall Pigs. Mimeo. Lft. No. 60, A.H.D., B.A.I., U.S.D.A.
4) Fairbanks, B. W., J. L. Krider, W. E. Carroll, 1945. Distillers' Byproducts in Swine Rations. III. Dried Corn Distillers' Solubles, Alfalfa Meal, and Crystalline B-vitamins Compared for Growing-fattening Pigs in Dry Lot. Jour. An. Sci., Vol. 4, No. 4, pp. 420-429.
5) Ferin, E. F., 1946. Addition of Synthetic Nutrients to Protein Supplemental Feeds in Swine Rations. Jour. An. Sci., Vol. 5, No. 1, pp. 42-46.
6) Goss, W. H., 1942. The Chemistry and Technology of the Soybean and Its Derived Products, Part II. Processing of Soybeans and Soybean Products. Mimeo. Cr.C.E., 142, Part 2, pp. 1-69. Bur. Agr. Chem. and Eng., U.S.D.A.
7) Hammond, J. C., 1942. Cow Manure as a Source of Certain Vitamins for Growing Chickens. Poutry Sci., 23: 471, Nov.
8) Hayward, J. W., G. Bohstedt, J. M. Fargo, 1934. Soybean Oil Meal Prepared at Different Temperatures as Feed for Pigs. Proc. 27th An. Mtg. Am. Soc. of An. Prod., pp. 123-126.
9) Krider, J. L., D. E. Becker, R. F. Van Poucke, M. F. James, 1948. Crystalline or Crude Concentrates of B-Vitamins Supplement a Corn-Soybean Meal Ration for Weanling Pigs in Dry Lot. Jour. of An. Sci., Vol. 7, No. 4, pp. 501-508.
10) Luecke, R. W., W. N. McMillen, F. Thorpe, Jr., and J. R. Boniece, 1949. The Effect of Vitamin B_{12} Concentrate on the Growth of Weanling Pigs Fed Corn-Soybean Diets. Science 110: 139-140, Aug.
11) McGinnis, J., J. M. Stevens, K. Groves, 1947. The In Vitro Synthesis of a Chick Promoting Factor in Hen Feces. Poultry Sci., 26: 442, July.
12) Markley, K. S., 1942. *The Chemistry and Technology of the Soybean and Its* Derived Products, Part I. Chemical Composition and Properties of Constituents and Derived Products. Mimeo. A.C.E., 142, Part I, pp. 1-112, Bur. Agr. Chem. and Eng., U.S.D.A.
13) Neuman, A. L., J. L. Krider, B. C. Johnson, 1948. Unidentified Growth Factor (s) Needed for Optimum Growth of New-born Pigs. Proc. Soc. Exp. Biol. Med., 69: 513.
14) Neuman, A. L., M. F. James, J. L. Krider, B. C. Johnson, 1949. Essentiality of Vitamin B_{12} for the Baby Pig With Preliminary Quantitative Data. Federation Proc. 8: 391, March.
15) Neuman, A. L., J. B. Thiersch, J. L. Krider, M. F. James, B. C. Johnson, 1950. Requirement of the Baby Pig for Vitamin B_{12} Fed as a Concentrate. Jour. An. Sci., Vol. 9, No. 1, pp. 83-89.
16) Rickes, E. L., N. G. Brink, F. R. Koniuszy, T. R. Wood, K. Folkers, 1948. Vitamin B_{12} a Cobalt Complex. Science 108: 134, Aug.
17) Rickes, E. L., N. G. Brink, F. R. Koniuszy, T. R. Wood, K. Folkers, 1948. Comparative Data on Vitamin B_{12} from Liver and from a New Source, Streptomyces griseus. Science 108: 634-635, Dec.
18) Robison, W. L., 1930. Soybeans and Soybean Oil Meal for Pigs. Ohio Agr. Exp. Sta. Bul. 452.
19) Robison, W. L., 1930. Fiber in Rations for Growing and Fattening Pigs. Ohio Agr. Exp. Sta. Bi-Mo. Bul. No. 145, pp. 102-107.
20) Rubin, M., H. R. Bird, 1946. Chick Growth Factor in Cow Manure; I. Its Nonidentity With Chick Growth Factors Previously Described. Jour. Biol. Chem., 163: 387, May.
21) Rubin, M., H. R. Bird, I. Rothchild, 1946. A Growth Promoting Factor for Chicks in Feces of Hens. Poultry Sci. 25: 526, Sept.
22) Schmidt, E. W., 1934. Recent Developments Relating to Oil Extraction by the Solvent Process. Paint, Oil, and Chemical Review, Nov. 15, 1934.
23) Stokstad, E. L. R., T. H. Jukes, J. Pierce, A. C. Page, Jr., A. L. Franklin, 1949. The Multiple Nature of the Animal Protein Factor. Jour. Biol. Chem., 180: 647.
24) Vestal, C. M., 1921. Fiber in Rations for Fattening Swine. Rec. of Proc. of An. Mtg. of Am. Soc. of An. Prod., Nov. 1921, pp. 43-47.
25) Vestal, C. M., 1922-1923. Raw Soybeans Versus Processed (roasted) Soybeans as Supplements to Corn for Hogs in Dry Lot and on Pasture. An. Hus. Dept., Ind. Exp. Sta., Mimeo. Lfts. (not numbered).
26) West, R., E. H. Reisner, Jr., 1949. Treatment of Pernicious Anemia with Crystalline Vitamin B_{12}. Am. Jour. Med. 6: 643-650, May.
27) West, R., 1949. The Treatment of Addisonian Pernicious Anemia with Vitamin B_{12}. A.M.A. Scientific Assembly Official Program, p. 95, June.